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THE ROLE OF THE GERM IN THE NUTRITIVE PROPERTIES OF THE CEREAL GRAINS[1]

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Studies by McHenry and associates (1, 2, 3, 4, 5, 6, 7) have indicated that several members of the vitamin B complex are specifically concerned in fat metabolism. Feeding trials with swine in progress at Macdonald College have shown that addition of wheat germ to basal diets of protein-mineral fortified corn endosperm, wheat endosperm, or barley endosperm results in excellent growth of market pigs; but the carcasses produced are usually penalized for bacon quality because of excessive fat deposits. Corn germ has failed to stimulate growth to any marked degree when used in similar diets. Barley germ, in the single test made, appeared to behave similarly to wheat germ in supplementing barley endosperm.

In general, cereal grains used for human consumption are degermed. Dietary surveys indicate that the typical Canadian diet is frequently below optimum in some of the vitamin B family. Thus both from the human diet standpoint and that of the live stock feeder who utilizes the milling offal from the cereal grains the question of the specific nutritive properties of the germ fractions of the cereals is of importance.

The objects of the herein reported experiment were to learn whether diets similar to those fed to the bacon pigs, above noted, would produce comparable growth responses with young rats; and further to establish whether or not these effects were traceable entirely to certain members of the vitamin B group.

EXPERIMENTAL

Thirty young white rats averaging 70 grams in weight were allotted at random to 6 feeding groups of 5 animals each. The rats were caged and fed individually for a period of 56 days. The basal diet for all consisted of wheat endosperm and a mixed protein-mineral supplement. The latter was a combination of meat meal, fish meal, linseed oilmeal, limestone, bone meal, and iodized salt. The exact make up of the rations is shown in tabular form in Table 1.

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TABLE 1.—PERCENTAGE COMPOSITION OF DIETS FED

Constituent	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI
Degermed wheat	85.0	82.9	85.0	82.9	82.9	82.9
Protein-Mineral supplement	15.0	15.0	15.0	15.0	15.0	15.0
Wheat germ	—	2.1	—	—	—	2.1
Corn germ	—	—	—	2.1	2.1	—

The above diets and water were fed *ad libitum* but with individual records kept of feed consumption. One drop of cod liver oil concentrate was fed directly to each rat daily.

The rats in Lots III, V, and VI received five drops per day of an aqueous solution furnishing 20 y thiamin hydrochloride, 25 y riboflavin, 20 y pyridoxine and 85 y pantothenic acid. These quantities represented the averages of the published recommendations of some 15 laboratories, but otherwise have no specific significance as to optimum levels.

OBSERVATIONS DURING THE TRIAL

The first noticeable signs of disturbance of possible dietary origin was in Lots I, II, IV and VI where several of the rats developed hematurea. Rats in all lots also showed considerable loss of hair. A few of them were practically denuded by the end of the first month, but new hair in most cases began to grow in before the test ended.

The most striking differences, however, were in growth and feed consumption, which were evident practically from the start.

RESULTS

In Table 2 are summarized the average figures for daily gains in live weight, feed intake, and the gain adjusted to equal feed consumption.

TABLE 2.—MEAN DAILY GAINS AND FEED CONSUMPTION OF RATS DURING TEST

Lot	Ration supplement	Mean daily gains	Mean daily feed	Gains adjusted* to mean feed intake and average initial weight
		(Gms.)	(Gms.)	(Gms.)
I	None	1.36	11.2	2.22
II	Wheat germ	2.48	15.0	2.62
III	"Vitamin B" mixture	3.22	18.4	2.68
IV	Corn germ	1.54	13.2	2.18
V	Corn germ plus "B" mixture	3.48	19.7	2.81
VI	Wheat germ plus "B" mixture	3.22	17.4	2.80

* Differences greater than 0.31 grams are statistically significant with $P = .05$.

Variation in initial weight and feed intake between rats together accounted for 64% of the differences in gains of which three-quarters was traceable to differences in feed intake.

This effect of wheat germ and of the vitamin B mixture as compared to corn germ on feed intake is clearly evident from the figures of Table 2. As compared to the check lot, rats on corn germ ate 18% and those on wheat germ 34% more feed; while the B mixture stimulated a 60% increase in feed intake. Along with this increased intake of food with wheat germ and the crystallin B fractions there was an improvement in diet utilization indicated by a greater live weight gain per unit of food eaten, amounting to about 30%. Corn germ did not effect any qualitative improvement in the diet.

In explanation of these findings one would logically enquire as to the amounts of thiamin, riboflavin, pyridoxine, and pantothenic acid which were provided in the wheat germ and corn germ supplements. Analysis[4] yielded the following figures (gamma per gram material):

Item	Wheat germ	Corn germ
Thiamin	27.9	6.5
Riboflavin	8.2	3.8
Pantothenic acid	18.1	11.0

Though not directly applicable to the wheat and corn germ used in these tests, partial analysis[5] of the vitamin B components per gram of defatted samples may also be of interest:

Item	Defatted wheat germ	Defatted corn germ
Thiamin	33 gamma/gm.	25–35 gamma/gm.
Riboflavin	9 gamma/gm.	6 gamma/gm.
Pathothenic acid	26 gamma/gm.	14 gamma/gm.
Pyridoxine	15 gamma/gm.	—
Niacin	80 gamma/gm.	45 gamma/gm.
Biotin	450 (milli-gamma)	—
Inositol	2.5 mgs.	—
Choline	High	—

Average data for commercial wheat germ give 11 I.U. of B_1 per gram. This is equivalent to 33 gamma per gram.

Rats in Lot II ate (15 × 0.021) 0.315 grams of Wheat germ daily and hence had about 8.8 gamma thiamin intake from the wheat germ. This would make the intake per day per rat of this B fraction just less than half that fed in the B mixtures of Lots III, V, and VI.

[4] Courtesy of the Ralston-Purina Co., St. Louis, Mo., U.S.A.
[5] Courtesy of the VioBin Corporation, Monticello, Ill.

Relatively, the riboflavin intake in the wheat germ fed lots would be lower than that of thiamin, for the riboflavin content of wheat germ was less than one-third that of thiamin.

In view of the fact that wheat germ plus the B mixture gave no greater actual gain or feed consumption than the B mixture alone one might tentatively conclude that other nutrients of wheat germ including other members of the vitamin B complex normally found therein added nothing of importance to the basal diet. The slightly greater efficiency of the ration supplemented with both wheat germ and the B mixture is not statistically significant and arises entirely because rats in this group ate slightly less feed than those of Lot III (B mixture). On the same ground it may be argued that the chief contribution of wheat germ to the nutritive value of the basal diet was in one or more of the four components of the vitamin B complex included in the B mixture. In view of its composition and with the assumption that the rat should receive about equal amounts of thiamin and riboflavin it seems probable that riboflavin was an important limiting factor in the wheat germ supplement.

Corn germ on the other hand was quite evidently a less valuable supplement to the basal diet. The stimulating effect on the food intake was relatively small and without a proportional increase in gains, so that the efficiency of the ration eaten was the same as that in the check lot. If one of the functions of thiamin is expressed as a greater efficiency in the utilization of the diet (i.e. of the carbohydrate) then it would appear that corn germ contributes considerably less B_1 to the diet than does wheat germ. The known low nicotinic acid content of corn germ should not be a factor in rat trials.

Admittedly these findings, while confirming previous results with pigs at this station are incomplete. That they may be significant both in animal rationing and in problems of human diet seems highly probable and accordingly justify further studies designed to answer more specifically the many questions which these data present.

CONCLUSIONS

Corn germ and wheat germ are of markedly different nutritional value as supplements to a basal diet of wheat endosperm fortified with adequate proteins, minerals and vitamins A and D.

As measured by the results obtained by a daily supplement of 20 gamma each of thiamin, and pyridoxine, 25 gamma of riboflavin, and 85 gamma of pantothenic acid, wheat germ furnishes an appreciable amount of these B fractions. The intake through wheat germ of thiamin was about one-half and of riboflavin one-third that fed in the B mixture. Feed intake was 34% greater with wheat germ supplement and 60% greater with the B mixture than in the check lot. Gains per unit of food eaten as a result of these supplements were 30% greater than in the check lot.

Corn germ stimulated only an 18% increase in food consumption and failed to improve the efficiency of the diet.

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ADDENDUM

Since the preparation of this manuscript results have come to hand of rat feeding tests by McHenry and Patterson[6] at the School of Hygiene, University of Toronto in which samples of the wheat germ and corn germ used in our studies were incorporated as 4% of their standard fat-free basal diet (casein 10, sucrose 84, salt mixture 4, agar 2, and cod liver oil concentrate 0.015). An abstract of McHenry's report follows.

After 24 days of feeding on the basal diet the average weight of the 60 rats used had declined from 89 to 56 grams and they were presumed depleted of B vitamins. They were then divided into 6 groups, with equal weight distribution in each group to make the groups comparable. One group was killed for fat determinations and the other 5 groups were continued as follows:—

Group 2—basal diet only
Group 3—basal diet plus 4% wheat germ
Group 4—basal diet plus 4% corn germ
Group 5—basal diet plus thiamin (25 gamma per rat per day)
Group 6—basal diet plus thiamin (as shown) plus riboflavin (20 gamma) plus pyridoxine (20 gamma) plus calcium pantothenate (100 gamma).

"The results of fat determinations done after one week of supplementation, are as follows:—

Group	No. of rats surviving	Average per cent body fat	Average per cent liver fat
Basal after 3 weeks	10	2.5	3.9
Basal after 4 weeks	6	1.6	3.8
Wheat germ	10	4.8	5.2
Corn germ	7	1.8	2.9
4 "B" Vitamins	10	5.6	18.1
Thiamin	10	4.9	18.1

[6] Personal communication.

"There are several comments which could be made on these data. They are exactly what we expect from previous work. Fatty livers were produced in the last two groups because of the lack of choline; in these groups the evidence of fat synthesis is clear. There is equally good evidence of fat synthesis in group 3 (wheat germ) but no fatty livers were found owing to the high choline content of wheat germ.

"No fat synthesis was produced by corn germ and this means, to us, almost complete absence of thiamin. All the other B vitamins can be supplied but no fat synthesis will occur unless thiamin is present. Corn germ may contain all other B vitamins but, in my opinion, it does not contain thiamin."

THE EFFECT OF BORON APPLICATIONS ON THE SUBSEQUENT STORAGE AND PHYSIOLOGICAL BEHAVIOUR OF McINTOSH APPLES[1]

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Boron deficiency problems in apples, mainly in the form of cork, have been evident in orchards throughout the world for some time. By the judicious application of boron compounds to the soil, the leaves, or by other means, the cork problems have been eliminated.

With corrective measures other than boron secondary problems nearly always arise by the fact that the physiological functions of the plants have been otherwise disturbed. It would be natural to assume then that even if boron were applied by the most careful means to control cork that secondary effects either deleterious or otherwise might occur.

From observations made in apple orchards it has been noted that boron applications have delayed fruit abscission, the onset of yellow ground colour, and fruit softening. This would strongly suggest that the general maturity progress of the fruit is slowed down or interfered with in some way.

Furthermore, the physiological age or maturity of the apple has been shown by practically all storage investigators to be of the utmost if not the most important factor on the subsequent storage behaviour of apples. Beyond this many investigators have illustrated that many of the ill-effects in storage resulting from pre-storage treatment have been brought about by an increase or decrease in rate of maturity. Hence it would not be surprising that if boron does affect maturity progress that subsequent ill-effects might develop in storage.

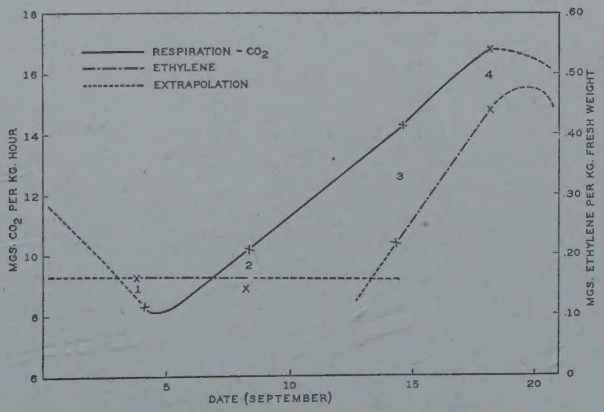

FIGURE 1. CO_2 Production and Ethylene Content of McIntosh Apples on the Tree—estimations made from initial rates and trends of apples immediately after harvest—all studies at 60° F. in the laboratory.

[1] Contribution No. 601, Division of Horticulture, Experimental Farms Service and Scientific Contribution No.96, Division of Chemistry.
[2] W. R. Phillips, Assistant in Low Temperature Research, Horticultural Division.
[3] F. B. Johnston, Assistant Chemist, Chemistry Division.

On referring to the literature on the effect of boron on the storage behaviour of apples it is found that boron does affect storage behaviour. The evidence in this connection appears to be somewhat contradictory, however. Chittenden and Thompson (2), for example, show a deleterious affect while Powers (5) shows an increase in storage life. Of course, there are other possible explanations for these contradictory results but if the influence of boron is an indirect one through its influence on maturity, contradictory results of this nature can be expected. If, for example, maturity is delayed naturally those disorders associated with immaturity will be increased and those associated with over-maturity decreased. Then it is obvious with variations of variety and cultural conditions that maturity delay will be beneficial in one instance and deleterious in others. The whole problem of boron applications is too involved to have such a simple explanation but at any rate it would be harmless to regard this maturity effect as a possible trend.

METHODS

The major portion of the material used in the experiment was made up of McIntosh apples grown in an orchard at Brighton, Ontario. These particular trees have been under observation for several years in conjunction with boron application studies. All the methods of boron application are represented, such as, broadcast, injection and spray methods of application. Other McIntosh apples from an orchard at Iroquois, Ontario, were also used to establish respiration and ethylene trends as a standard of comparison. The reason for this was that apples could be selected from a particular tree of which the past history was known.

Storage observations were made on apples harvested on September 16, 1938, from the above mentioned boron plots. These apples were shipped and stored within 36 hours of harvest. Previous to storage, however, random samples were made up of about 100 apples each. This was done by taking an equal number of apples from each package containing fruit from one plot of given boron treatment. The apples were individually wrapped in an odourless mineral oil paper wrap. Excessively large and small, bruised or otherwise damaged or abnormal apples were rejected. An equal number of samples were stored at 32°, 36°, and 39° F. The main examinations were made after 123 and 140 days, respectively. A few surplus samples were left at 32° F. for 211 days for maximum development of storage disorders. The fruit in every instance was allowed to ripen for 7 days at 65° F. and 90% relative humidity. After removal from the storage room at these times quality and injury records were made.

Some difficulty was encountered in distinguishing between corky core and core flush. This was due to the similarity in the macroscopic appearance of these two disorders. Hence the first problem was to establish a reliable means of distinguishing these disorders which would check with the histological examinations. These points of difference were as follows.

(1) The origin of core flush was found to be in the core area just internal to the petal bundles. From here the disorder was found to spread to the carpels and approach them. Thus in advanced stages the disorder

assumes a similar design to that of the carpel walls, producing a star-shaped effect. Corky core, on the other hand, usually commences just inside and on either side of the sepal bundles. In advanced stages other areas in the core region may become affected. These areas may become more or less contiguous, in which case a mottled effect is produced.

(2) In core flush there is no definite line of demarkation between damaged and healthy tissue. In corky core there is usually a definite line of demarkation between injured and healthy tissue.

(3) The damaged area in core flush is pinkish-brown in colour and appears moist and somewhat soft. In corky core the affected areas are light brown in colour but usually have more lustre than the core flush areas. The cork areas also have a tendency to appear drier and harder in texture than core flush.

(4) In core flush the endocarp can be separated from the contiguous fleshy tissue quite readily whereas endocarp maintains its characteristic retention if the apple is affected with corky core. This difference can be readily noticed when making a transverse section of the apples, particularly if the knife is somewhat dull.

On the basis of the above distinguishing features it was estimated that the maximum possibility of error in diagnosis was less than 5%.

Respiration studies were carried out with individual apples representing three maturities from a boron treated and non-boron treated plot. These apples were placed in the respiration chambers and measurement of carbon dioxide output was commenced within 36 hours of picking. The measurement of respiration by carbon dioxide evolution was made by the usual Petenkoffer method. By this system the total carbon dioxide output per apple was measured at 60° F. The final calculations were made on the basis of mg. of CO_2 output per kgm. original fresh weight.

The method used for determination of ethylene in this work was that of Nelson (3), of which a brief description is here given.

About 200 ml. of water are placed in a 500 ml. Erlenmeyer flask which is then stoppered and weighed. A sample of apple tissue is introduced and the whole again weighed. The flask is then attached by a ground glass joint to a reflux condenser, to the top of which in turn is fitted an evacuated gas sampling bulb with pressure tubing.

The stop-cock of the gas sampling bulb is opened, placing the whole system under a vacuum. By cautious boiling the gases, alcohol, acetaldehyde, and esters contained in the apple are finally all collected in the bulb.

The contents of the bulb are then passed over sodamide, which removes all permanganate-reducing substances save ethylene, into a specially adapted evacuated round bottom flask. Into this flask is introduced a known volume of standard permanganate in dilute sulphuric acid and the assembly rotated for an hour to increase the gas-permanganate surface.

An aliquot of the permanganate is withdrawn and run into an excess of standard ferrous ammonium sulphate solution, 2 drops of 85% phosphoric acid added, and the back-titration carried out. An equal aliquot of the standard permanganate is treated similarly. From these values the amount of ethylene is calculated.

Boron analyses were made spectroscopically. Estimations were made on the basis of parts per millions of dry weight.

RESULTS

Previous to the actual experiment, boron analyses were made on samples of apples from the various plots. The results of these analyses are recorded in Table 1. As well as this, the extent of corky core found in samples of apples from the same plots are included.

What will be noted in Table 1 is that the boron analyses at harvest showed a decrease from those taken earlier (August 27). This may or may not have a physiological significance. It will also be noted that the amount

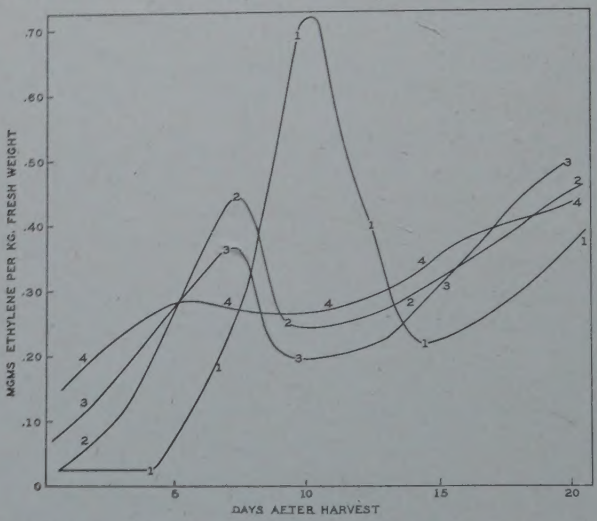

FIGURE 2. Trend of Ethylene Content at 60° F. in McIntosh Apples from Healthy Tree—numbers indicate trend curve for apples harvested at dates corresponding to numbers on Figure 1.

of corky core at harvest does not in all treatments show a direct correlation to the amount of boron present. One important feature that is brought out is it would appear that just sufficient boron has been present to control the cork troubles. In other words the treatments under consideration can in no way be considered as excess considerations. For this reason the problems encountered in this experiment are not those associated with boron excesses, but rather are problems a fruit grower may encounter when applying boron by the most careful and prescribed methods.

TABLE 1.—BORON ANALYSES AT AND PREVIOUS TO HARVEST AND CORKY CORE INDICES AT HARVEST (MCINTOSH) FROM PLOTS USED IN EXPERIMENT*

Treatment	Boron Aug. 27, 1938	Boron at harvest	Corky core index at harvest
	p.p.m.	p.p.m.	
Boric acid broadcast spring, 1937	21.0	20.0	21.0
Boric acid spray, 1937	13.5	10.0	18.0
Boric acid injected, 1937	20.0	10.0	0
Boric acid broadcast fall, 1936	18.0	16.0	0
Check (no boron added)	10.0	3.0	98.3

* In this and other tables the injury index is computed from totalling the resulting products by multiplying the percentage of fruit affected to a slight degree by 1. to a moderate degree by 2, and to a severe degree by 3.

Observations made in the orchard, previous to harvest, revealed that the boron treated plots in general appeared to be less mature than the check or non-treated plots. The boron plots had less blush or red colour and were somewhat greener. They were also slightly harder to separate from the tree.

The maturity data resulting from observations previous to storage, however, did not altogether support these findings. These data showed no significant retardation of ground colour or starch reductions. It was noted, however, that the check plots were more highly blushed than were the boron treated plots. By pressure test measurements no significant retardation of maturity was noted by boron treatment. Thus by the usual maturity standards it might be said that the boron treatment did not greatly reduce maturity progress.

Samples of the treatments outlined in Table 1 were examined for core flush and corky core after 100, 123 and 140 days in storage at 32°, 36° and 39° F. and 7 days ripening at 60° F. Another examination at 211 days, of samples stored at 32° F., was also made. Since no appreciable core flush had developed at the 100-day examination this has been omitted in Table 2.

TABLE 2.—CORE FLUSH AND CORKY CORE (INDICES) IN McINTOSH APPLES FROM BORON PLOTS AT BRIGHTON, ONTARIO, AFTER STORAGE AT VARIOUS TEMPERATURES

	Injury	Examination I 123 days			Examination II 140 days			Examination III 211 days	
		32° F.	36° F.	39° F.	32° F.	36° F.	32° F.	32° F.	Totals
B.A. injected, 1937	Core flush	11	22	1	15	55.5	0	31.6	136.1
B.A. spray, 1937	Core flush	7	20	9.1	13	42	1	43.3	133.4
B.A. broadcast spring, 1937	Core flush	29	71	9.5	32	63	10	78.0	292.5
B.A. broadcast fall, 1936	Core flush	19	56	4.0	30	57	8	—	203.0
Check plot	Core flush	3	33	3.0	20	40	1	—	116.7
B.A. injected, 1937	Corky core	0	0	5.3	3	0	0	2	10.3
B.A. spray, 1937	Corky core	20	0	8.0	7	1	5	5	46.0
B.A. broadcast spring, 1937	Corky core	0	1	0	7	0	0	0	8.0
B.A. broadcast fall, 1936	Corky core	5	0	0	2	0	0	5	12.0
Check	Corky core	76.5	49	41.6	59.5	57	20.5	24.0	319.1

From Table 2 it can be seen that boron applications have resulted in a considerable increase in core flush production or, conversely, the absence of boron has resulted in core flush reduction.

Where core flush is present it will be noted that increasing the storage temperature to 39° F. has resulted in a significant reduction in the amount of core flush. What is also conspicuous is that corky core indices are not consistently influenced by storage temperature. The fact that there is an apparent reduction in the amount of cork as compared to Table 1 (corky core at harvest) may be explained by the method of selecting samples.

Another point of interest is that if the total injury columns are compared with boron analyses at harvest in Table 1 it will be seen that there

is a close correlation between quantities of boron and core flush. Similarly, there appears to be a converse relationship between core flush and corky core totals.

Respiration trends were again established from apples on the same tree as previously studied (4). The same characteristic trend was noted except that the whole curve was advanced by about 10 to 14 days. The climacteric occurred at about September 20 as compared to October 5 of the previous year.

Figure 1 illustrates this respiratory trend along with ethylene determinations. It will be noted that the ethylene content remains at a low level until the climacteric rise is fairly well advanced. On the other hand, maximum ethylene content is reached about the same time as the climacteric peak. An important feature is that the sharp increase in ethylene content just precedes ground colour change from green to yellow, which also marks the point of loss of susceptibility to core flush in normal apples. The advantage of using ethylene content as a gauge of maturity is then obvious.

In Figure 2 is shown the ethylene content trend of apples from the same tree harvested at the points marked in Figure 1. It will be noticed that 1 is definitely preclimacteric, while 2 and 3 are on the climacteric rise, and 4 is approximately at the peak.

The difference of ethylene trends of apples harvested at the various stages will be readily noted. At the successive stages of maturity the maximal ethylene content points are reached before this point is reached on the tree, but these maximal points decrease with senescence. Further-

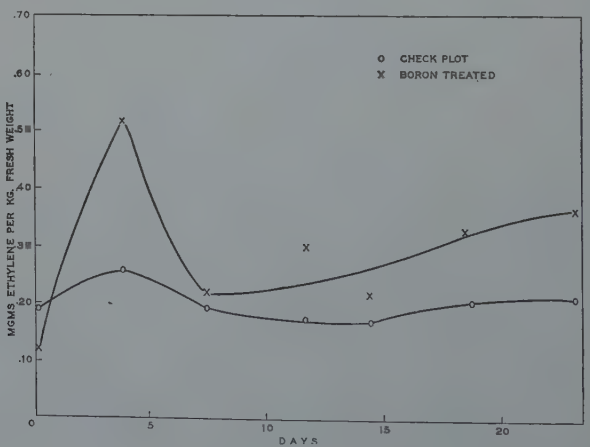

FIGURE 3. Trends of Ethylene Content at 60° F. of McIntosh Apples from Boron Plots Harvested Sept. 18.

more, the secondary rise, after the maximal point, shows a tendency to commence at higher rates with later maturity. If ethylene determinations were continued undoubtedly another decrease would be noted forming a second hump, as was found by Nelson (3).

The respiration curve (CO_2 output) of McIntosh apples from the boron plots at Brighton, although indefinite, suggested that both boron treated and check plots were on the climacteric rise at the first gathering on

September 18. The second gathering on September 24 indicated that two of the three check plot apples were beyond the climacteric peak, whereas all three of the boron treated apples required 5 to 7 days at 60° F. to reach the climacteric peak. The third gathering on October 10 indicated that all apples were beyoud the climacteric peak. In other words, the check plots would have the following relationship to the curve in Figure 1.

Gathering 1 corresponds with point 3.
Gathering 2 corresponds with point 4 or slightly beyond.
Gathering 3 corresponds with a point well beyond point 4.

Similarly, the apples from the boron treated plot would have this relationship with the respiration curve on Figure 1.

Gathering 1 corresponds with a point slightly less than 3.
Gathering 2 corresponds with point 3 or slightly more.
Gathering 3 corresponds with a point beyond point 4.

By spectroscopic analyses the actual boron contents of the apples studied for CO_2 production revealed that the apples from the check plots contained 3.0 to 4.0 p.p.m. boron and the boron treated plot ran from 12 to 30 p.p.m. on the basis of dry weight (the bulk of the boron treated apples ranged from 17 to 22 p.p.m.)

Ethylene content curves at 60° F. from the first gathering of the boron plots are shown in Figure 3. It will be seen that the ethylene trend from the plot receiving boron differs radically from the plot suffering from boron starvation. When compared to Figure 2 it will be seen that the apples with higher boron content have a curve similar to curve 2 or 3. Higher initial rates might be explained by the fact that a longer time elapsed in shipping apples from the boron plots than from the orchard in which Figure 1 apples were grown.

On the other hand, the low boron apples appear to have an ethylene trend similar to curve 4 at the outset but fails to show as steep a secondary rise. At any rate the boron treatment curve in its entirety is more like that of apples from well nourished trees than is the curve of the low boron apples. There is also a definite indication that the boron treatment results in an ethylene trend of a less mature character than that of the boron starved apples.

In Figure 4 are set forth the ethylene content trends of apples from the boron plots at the third gathering harvested October 2. (No ethylene determinations were made on second gathering.) On comparing the curve of the boron treated sample with Figure 2 it will be seen that this curve is very similar to curve 4. This suggests that these apples were harvested at or near the peak of the climacteric occurring on the tree.

The curve for the boron starved samples, however, appears unlike any of the curves in Figure 2. It will be noted that the initial rates of ethylene content for this curve are uniform at a moderately high level. After the fifth day these rates show an increase followed by a decline. Respiration rates for similar apples suggest that the boron deficient specimens are all well beyond the climacteric peak at this time. Assuming that a second peak occurs (Nelson loc. cit.) then it would appear that this curve represents a stage of maturity further advanced than any ethylene curve in Figure 2.

During the subsequent year (1939) McIntosh apples were again harvested from the boron plots. Two separate gatherings were made at approximately 1 week's interval. The purpose was to see if a delay in harvesting boron treated apples would result in advanced maturity which might in return bring about a reduction in core flush.

Gathering I, picked on September 16th, showed all samples to be immature. The ground colour showed no signs of yellowing and the starch content was high. Maturity II showed considerable advance in ground colour as well as starch reduction. There was no great difference between the check plot and the boron treated plots as far as these maturity criteria were concerned. There was just a slight suggestion, however, that the check plots were further advanced. No respiration or ethylene trends were made. All samples were stored at 32° F.

An examination on February 26th revealed that pick II in all treatments showed a marked increase in quality (flavour and texture). The check plots were superior in quality to the boron treated plots in both gatherings I and II. The core flush index in the check plot was reduced from 21.1 to 3.9 between the first and second gatherings. In all the boron plots the mean core flush index was reduced from 81.3 to 58.4.

During this year corky core was evident in some of the boron treated plots, but in no instance was this nearly as much as in the check plots. The mean corky core indices for these boron treated plots were 66.1 and 61.5 for the first and second gatherings respectively. On the other hand, the plots showing no corky core (which would possibly be higher in boron content) showed core flush indices of 111.6 and 52.0 for the first and second gatherings. Thus the effect of delay in harvest on boron treated apples is apparent. It will be noted, however, that the reduction in core flush with advanced maturity is not as great as would be expected as judged by the usual maturity standards.

DISCUSSION AND CONCLUSIONS

The results set forth leave little doubt that the application of boron to trees which are deficient in this element results in an increase in a cold storage disorder known as core flush. This applies when the boron levels in the fruit tissues are increased to levels not normally considered excessive. However, past work has shown that core flush is tied up with maturity. When McIntosh were harvested at points previous to the climacteric peak and before yellowing commenced, large amounts of core flush developed in storage; whereas if the apples were permitted to reach the climacteric peak either on or off the tree before exposure to low temperature a considerable reduction in core flush was noted. Temperatures at 36° F. or below have also increased core flush as compared to temperatures of 39° F. and above.

It is quite reasonable, therefore, to suspect that if boron applications increase the amount of core flush the boron effect is tied up with the maturity progress of the apple.

Field observations have confirmed this opinion in that from general observation the boron treated apples appeared less mature than the boron deficient apples on the tree. Examination of the harvested apples, however,

did not altogether confirm these observations. There did, however, appear to be some maturity delay in boron treated apples.

Maturity drift as gauged by carbon dioxide output of individual apples has shown a tendency for apples with higher boron content to reach the climacteric peak at a later stage than boron starved apples. This trend, although not absolute, further confirms the original observations that boron applications have delayed maturity progress.

In connection with ethylene content determinations of apples it has been shown here and by others (3) that these have a definite association with carbon dioxide output trends in McIntosh apples. It has further been shown that ethylene trends assume a characteristic curve depending on the stage of maturity at which the apples were harvested. In the two

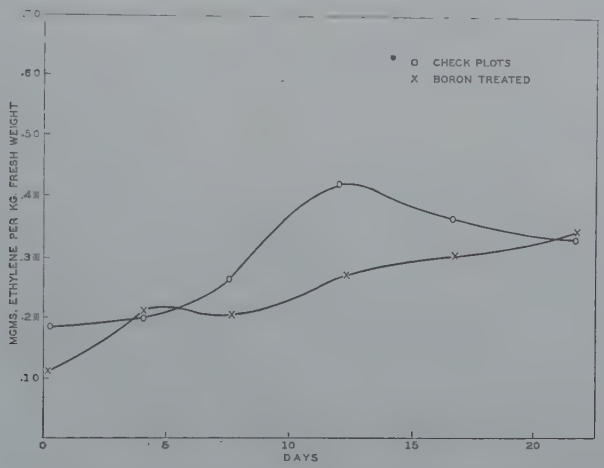

FIGURE 4. Trends of Ethylene Content at 60° F. of McIntosh Apples from Boron Plots—Harvested October 2.

gatherings of apples from the boron plots it has been revealed that these ethylene trends conform more closely to more immature apples in the case of higher boron apples than in low or boron starved apples. This tendency is much more definite than any of the other criteria. Thus the evidence supporting the maturity effect of boron is further enhanced.

The results of core flush development in storage found in 1939–40 provide a certain amount of substantiating evidence. These results also show that other complexities exist in that core flush reduction is not proportional to maturity advance in the boron treated apples. Even though the core flush index in boron treated apples showed a maximum reduction from 111.6 to 52.0 (index) by delaying harvest it is not as great as would be expected. On the basis of past experience in relation to maturity standards the core flush of second gathering should have been practically eliminated.

Another disconcerting factor is that although carbon dioxide and ethylene trends have been materially affected by boron content these effects are not proportional to the effect on ground colour change. It is usually accepted that ground colour changes from green to yellow are

influenced by ethylene production. It must be remembered that the ethylene determinations made represent ethylene accumulations which would be influenced by the rate at which this substance was being used up or dissipated as much as by the rate at which it was being produced.

The important point, as far as practical application is concerned, to be gleaned from these experiments is that boron applications have a delaying effect on the maturity progress of McIntosh apples. It would also appear that by delaying the harvest of these apples in comparison to boron starved apples it would appreciably help in the control of core flush developing in storage.

SUMMARY

Experiments were conducted to study the effect of boron applications in the orchard to the subsequent behaviour of the apples in storage. The McIntosh variety was used.

It was noted that boron applied to the extent recommended resulted in a considerable increase in core flush development in storage.

Observations in the orchard and after harvest suggested that boron tended to delay maturity progress.

A study of respiration trends (evolution of carbon dioxide) showed that boron appeared to delay the climacteric.

Ethylene contents of healthy McIntosh apples were determined and the resulting trends correlated with respiration. It was noted from these studies that characteristic ethylene trends were evident at various maturities or harvesting dates.

The effect of boron on these ethylene trends was such as to definitely establish the fact that at least some phases of maturity progress were influenced by boron content.

Subsequent application of these principles showed that core flush in boron treated apples could be materially reduced by delaying harvest.

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L'INDICATEUR PILOTE—A NEW RAPID CHEMICAL SOIL TEST

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Great interest has been shown throughout the world during the last two decades in the development and use of rapid chemical soil tests.

In Quebec comparatively little information is available on the range of fertility of the various soils in so far as their content of available nutrients is concerned. So far, the only rapid chemical test used in the Province of Quebec is the La-Motte test kit which has been adapted and calibrated to the coarse soil texture of Connecticut. Since this method has not always been satisfactory, it has been the authors' endeavour to devise a cheap, rapid and more reliable method of analysing soils either in the field or in simply equipped routine laboratories.

With this in view the purpose of this investigation was to determine the available nutrient level of certain soils and to calibrate the results of the rapid chemical tests with the known fertilizer response from field experiments.

L'Indicateur Pilote, an improvement of Rapid Chemical Soil Test, developed at Faculté d'Agriculture, Ste-Anne-de-la-Pocatière, P.Q.

From this research work resulted a new rapid chemical test, "Indicateur Pilote," which was named after the founder of the Agricultural College of Ste-Anne-de-la-Pocatière, P.Q.

This method has been checked against many chemical soil tests already in use, and has been studied in the field and in the laboratory. The results which, so far, have proved to be quite efficient and satisfactory, are outlined in the following pages.

SOIL TESTS STUDIED

As various rapid chemical tests have been developed in the different Universities of Canada and the United States, the first phase of this project dealt with an attempt to select two of the more promising methods, one

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for potassium and the other for phosphorus. In order to calibrate these methods to local soils and types of culture, a systematic comparative study of the Spurway, Thornton, Bray and Morgan rapid soil tests for phosphorus and potassium was undertaken in this institution with the helpful collaboration of the Ontario Agricultural College, Guelph, and the financial aid of the American Potash Institute.

These four methods were carefully subjected to study on a wide range of soils of known crop response. The Bray and Spurway methods were dropped after a few months of trial, because of lack of correlation with crop response, whilst the Thornton and Morgan methods received the authors' whole attention and careful study.

INDICATEUR PILOTE

The method "Indicateur Pilote" for phosphorus test is an adaptation of the Thornton modified method. This method was slightly modified. The extracting solution used is hydrochloric acid .05 N. Reagent No. 2 is an ammonium molybdate solution acidified with HC1. Stannous oxalate in solution is used as the reducing agent. A blue colour develops, the tint depending on the amount of phosphate in the soil. By comparing the tint with that of appropriate standards of known phosphate content the relative availability of phosphate may be judged. A small graduated stand with a scale of "Lb. of P_2O_5" on it has been devised to estimate the phosphorus soil content.

For the potash test the Morgan method was entirely modified in order to have it correlate with local soil fertility level, and to have its results more easily interpreted and appreciated. A highly buffered mixture of acetic acid (5%) and sodium acetate is used for the extraction of the soil sample. Potash content of the filtrate is then estimated by the turbidity produced with sodium cobaltinitrite and ethyl alcohol.

The intensity of the precipitate is estimated with the help of a small graduated stand. The number of pounds of potash per acre is estimated by diluting the potassium precipitate until lines behind the small vial used become visible. A scale adhering to the stand indicates directly the potash soil content (Lb./acre.).

LABORATORY EXPERIMENTS

The methods that have been compared are: l'Indicateur Pilote, La-Motte, Thornton, and Neubauer. This last one is a biological method which determines the soil content of available nutrients. It is used as a standard in the calibration of other rapid chemical soil tests. The Pilote method has been calibrated in order to correlate its results with the Neubauer method.

The data presented in Table 1 show the results obtained from the methods under study. The Neubauer analyses were made in the Soils Laboratory of the Ontario Agricultural College, with the collaboration of Prof. G. N. Ruhnke, Chief of the Chemistry Department, and C. Rivaz, Soils Specialist.

TABLE 1.—COMPARISON OF NEUBAUER ANALYSES WITH L'INDICATEUR PILOTE, LA MOTTE, AND THORNTON FOR POTASSIUM AND PHOSPHORUS ON DIFFERENT TYPES OF SOIL

No.	K_2O per acre				P_2O_5 per acre		
	Neubauer	Pilote	La Motte	Thornton	Neubauer	La Motte	Pilote
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1	34	60	120	175	76	75	75
2	36	50	—100	100	36	50	50
3	60	60	115	150	14	20	5
4	60	60	100	200	115	100	110
5	64	50	—100	75	40	50	50
6	70	50	—100	100	4	25	0
7	78	50	—100	125	122	75	120
8	85	50	—100	125	52	35	50
9	85	55	110	125	34	60	20
10	96	60	100	200	44	50	50
11	104	60	120	150	113	120	100
12	104	60	105	100	0	75	0
13	118	60	120	125	10	25	60
14	120	60	—100	100	58	100	15
15	126	100	100	150	38	50	50
16	128	120	120	200	124	50	130
17	130	80	160	300	13	40	50
18	130	100	—100	200	60	50	50
19	130	100	100	150	66	100	50
20	142	80	—100	200	28	40	75
21	148	150	105	200	178	75	150
22	148	210	140	400	142	60	100
23	148	210	140	400	142	40	120
24	152	125	100	100	6	100	0
25	156	125	120	125	42	75	0
26	161	150	120	300	17	10	10
27	162	200	130	300	106	50	100
28	180	120	120	300	16	50	30
29	188	200	100	300	102	75	100
30	198	100	100	200	8	100	60
31	208	125	—100	200	14	75	10
32	210	120	—100	175	182	50	175
33	212	225	140	425	0	50	0
34	212	180	100	275	34	50	50
35	230	235	160	500	14	30	5
36	265	275	180	500	8	50	10
37	276	200	100	300	18	50	10
38	298	325	200	525	96	35	75
39	298	200	120	300	70	100	75
40	316	300	300	525	22	30	10
41	318	200	160	300	124	75	10
42	355	220	130	325	106	50	90
43	364	100	100	225	119	50	5
44	364	125	100	200	119	75	5
45	374	125	—100	325	54	50	50
46	382	225	110	300	18	150	10
47	382	200	—100	300	83	50	10
48	384	200	100	300	6	50	25
49	411	225	150	400	38	50	25
50	446	225	120	400	50	50	20
51	600	250	160	400	74	50	60
52	836	250	150	400	136	75	60
53	873	300	180	400	34	60	25

The 53 test results of soil samples that have been presented in Table 1, are illustrated in Figures 1 and 2. In order to present the general trend and to secure a better view of the correlation existing between the results of the compared methods, the first and last samples in the series represent the extreme results of Neubauer analyses.

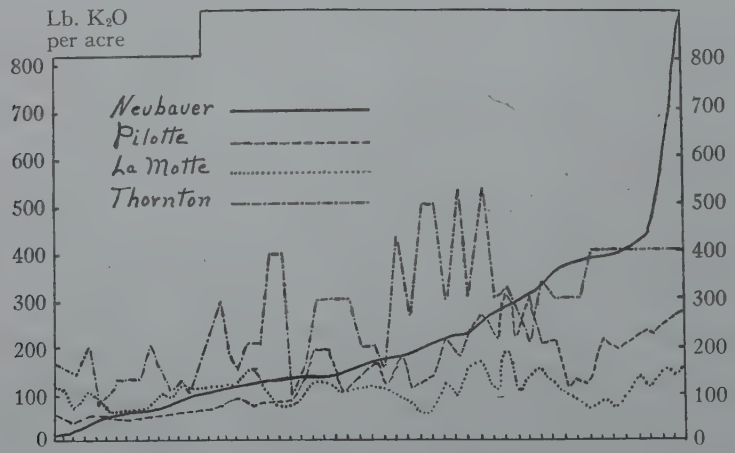

FIGURE 1. Comparison of Neubauer analyses with l'Indicateur Pilote, La-Motte and Thornton for potassium on different soil types.

The potash test results obtained with the Indicateur Pilote present the same trend as Neubauer analyses. However, about 23% of these results do not agree with the Neubauer method. La-Motte and Thornton have respectively 35 and 38% of their results which do not correlate with the Neubauer method.

Figure 2 presents data taken from Table 1. As in Figure 1, and for the same reason, the first and last samples in the series represent the extreme phosphorus results of Neubauer analyses.

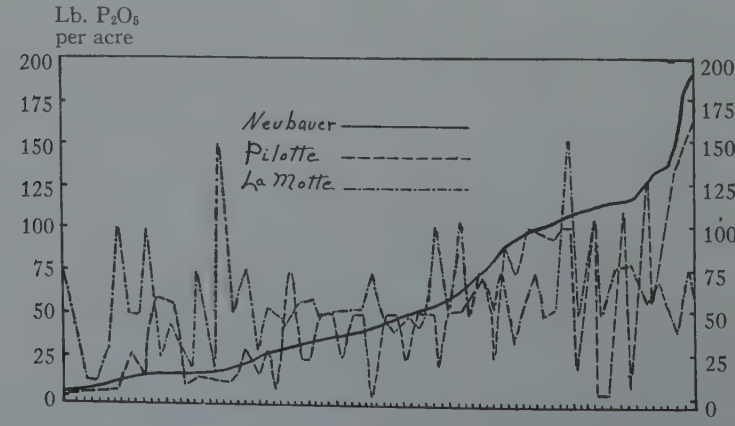

FIGURE 2. Comparison of Neubauer Analyses with l'Indicateur Pilote, La-Motte and Thornton for Phosphorus on Different Types of Soils.

FIGURE 2

On Figure 2, 60% of La-Motte results do not agree with those of Neubauer while l'Indicateur Pilote has only 25%. There exists therefore, a marked difference between those two methods.

TABLE 2.—COMPARISON OF NEUBAUER ANALYSES WITH L'INDICATEUR PILOTE, LA-MOTTE AND THORNTON FOR POTASSIUM AND PHOSPHORUS, ON SOIL SAMPLES TAKEN ON DIFFERENT FERTILIZER PLOTS

No.	K_2O per acre				P_2O_5 per acre		
	Neubauer	Pilote	La-Motte	Thornton	Neubauer	Pilote	La-Motte
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1	426	300	300	550	8	10	75
2	660	475	300	550	86	75	150
3	834	450	400	550	106	120	75
4	510	325	150	550	28	30	50
5	364	225	220	550	70	75	50
6	1170	1200	800	600	190	150	50
7	1152	1100	600	650	108	125	50
8	1956	1200	800	600	326	175	100
9	496	400	160	550	16	10	50
10	434	325	200	500	64	50	50
11	404	300	220	500	48	10	75
12	400	350	220	550	0	5	50
13	354	250	130	500	8	10	35
14	358	300	220	550	0	5	35
15	388	200	200	550	72	50	100
16	464	350	220	600	88	80	50
17	374	250	150	500	34	5	50
18	252	200	160	450	0	5	50
19	262	200	150	450	66	50	75
20	538	400	220	600	104	100	50
21	362	100	140	550	20	30	50
22	324	200	160	550	2	0	50
23	512	325	180	600	116	110	75
24	338	275	180	550	0	5	35

Figure 3 presents the data of the Table 2.

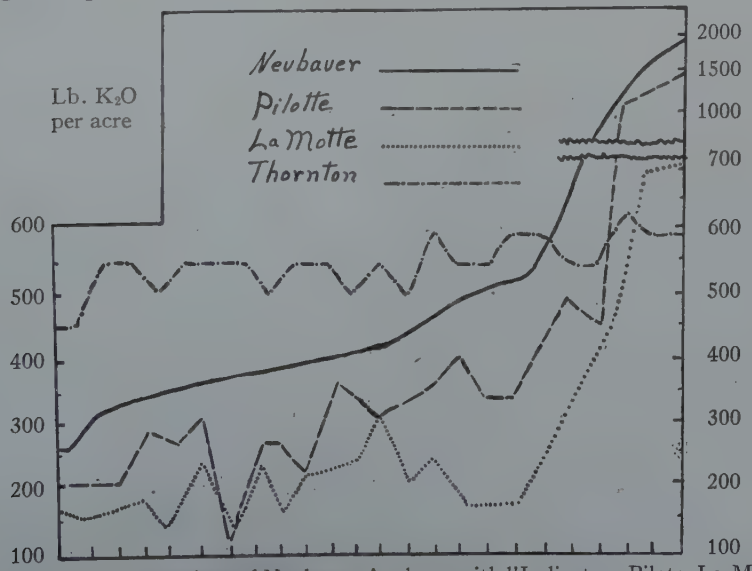

FIGURE 3. Comparison of Neubauer Analyses with l'Indicateur Pilote, La-Motte and Thornton for Potassium on Different Fertilizer Plots.

The analyses shown in Table 2 were made on 24 soil samples taken from fertilizer plots at the Experiment Station of Ste-Anne-de-la-Pocatière.

The potash test results obtained from l'Indicateur Pilote and La-Motte are quite inferior to those of Neubauer. However, the general trend of the Pilote results is the same as that of Neubauer. Thornton results do not correlate with any of the other methods.

Figure 4 will illustrate the phosphorus data presented on Table 2.

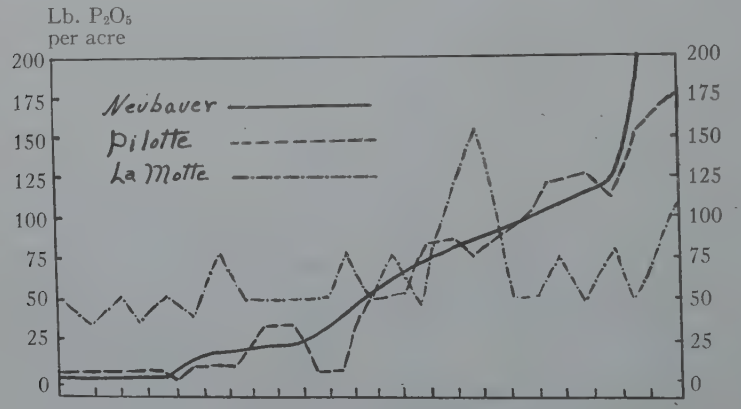

FIGURE 4. Comparison of Neubauer Analyses with l'Indicateur Pilote and La-Motte for Phosphorus on Different Fertilizer Plots.

There exists a very good agreement between the results of the Indicateur Pilote and those of Neubauer. As a matter of fact, 95% of the results are closely related to the Neubauer analyses. However, the La-Motte phosphorus test results present no correlation with that of Neubauer.

EXPERIMENTS CONDUCTED IN THE FIELDS

In order to estimate and put to further test the value and reliability of the Indicateur Pilote it was tried on a wide range of soils of known crop response. In the authors' opinion this is the best way to find out if a soil test is reliable or not.

With this in view, a series of experimental plots was started which received varied amount of fertilizers. On one plot the treatment was made according to the test results. Table 3 indicates the amount of fertilizers to be applied when the soil nutrient content is 10, 25, 50 lb., etc. of phosphorus, and 100, 200, 300 lb., etc. of potash. Table 3 presents the amount of fertilizer which was applied on either potatoes, turnips or oats.

As there was at hand no definite standard on which to depend for the exact amount of either phosphorus or potash that should be applied to the soil in order to meet adequately the plant needs, the quantity of fertilizers indicated on Table 3 was arbitrarily established. The amount of fertilizers applied on potatoes, turnips and oats was 2000, 750, and 400 lb. of x[3]–8–10 and x–12–10, and x–12–10, respectively. For lack of other standards these quantities are applied when the soil is found to be at its lowest fertility level.

[3] The experiments conducted herewith have not dealt with the nitrate fertilization. This explains why we have not taken into account the nitrates in our recommendation. The letter x may represent any quantity of nitrate.

TABLE 3.—FERTILIZER FOR POTATOES AS DETERMINED BY RAPID CHEMICAL SOIL TEST, "INDICATEUR PILOTE"

Test results		Pounds to be applied on soils		Corresponding formula
P_2O_5	K_2O	Super 20%	KC1 50%	Lbs. per acre
10	100	800	400	2000 lb. of x–8–10
25	200	700	350	1750 lb. of x–8–10
50	300	600	300	1500 lb. of x–8–10
75	350	500	250	1250 lb. of x–8–10
100	400	400	200	1000 lb. of x–8–10
125	450	300	150	750 lb. of x–8–10
150	500	200	100	500 lb. of x–8–10

FERTILIZER FOR TURNIPS AS DETERMINED BY RAPID CHEMICAL SOIL TESTS "INDICATEUR PILOTE"

Test results		Pounds to be applied on soils		Corresponding formula
P_2O_5	K_2O	Super 20%	KC1 50%	Lbs. per acre
10	100	420	140	700 lb. of x–12–10
25	150	360	120	600 lb. of x–12–10
50	200	300	100	500 lb. of x–12–10
75	250	240	80	400 lb. of x–12–10
100	300	180	60	300 lb. of x–12–10
125	350	120	40	200 lb. of x–12–10
150	400	60	20	100 lb. of x–12–10

FERTILIZER FOR OATS AS DETERMINED BY RAPID CHEMICAL SOIL TESTS "INDICATEUR PILOTE"

Test results		Lb. to be applied on soil		Corresponding formula
P_2O_5	K_2O	Super 20%	KC1 50%	Lb. per acre
10	100	240	80	400 lb. of x–12–10
25	150	180	60	300 lb. of x–12–10
50	200	120	40	200 lb. of x–12–10
75	250	60	20	100 lb. of x–12–10
100	300	0	0	0 lb. of x–12–10

CROP YIELDS OBTAINED ON FERTILIZER PLOTS WHERE THE TREATMENTS HAVE BEEN DETERMINED BY THE INDICATEUR PILOTE

Potato Experiments

Tables 4, 5 and 6 give the results obtained from potato plots. These experiments were carried on at St-Roch des Aulnaies in 1939, 1940 and 1941. The first experiment conducted in 1939 (Table 4) comprised 5 treatments

repeated twice making a total of 10 plots of 1/10 acre each. Two of these plots received the teatment prescribed by the Pilote test. The other plots received different amounts and served for comparison.

TABLE 4.—POTATO YIELDS IN 1939

Treatments per acre	Bushels of potatoes per acre			
	Total	No. 1	No. 2	Jumbo
(1) 1600 lbs. of 4–8–10 + 200 lbs. of Super + 640 lbs. of KC1.	307.5	171.0	18.8	105.7
(2) 800 lbs. of 4–8–10 + 100 lbs. of Super + 320 lbs. of KC1.	317.7	**247.6***	28.9	33.2
(3) 1600 lbs. of 4–8–10.	319.8	238.8	19.7	49.3
(4) 800 lbs. of 4–8–10.	302.7	219.7	19.5	47.3
(5) 10 tons of manure.	222.5	173.4	30.7	5.7

* Plot 2 received the treatment based on the rapid soil test "Indicateur Pilote."

Table 5 presents the potato yields in 1940. This experiment comprised 7 treatments repeated 3 times making a total of 21 plots of 1/38 acre each. Three of those plots received the treatment prescribed by the Pilote Tests. The other plots served as terms of comparison.

TABLE 5.—POTATO YIELDS IN 1940

	Treatments						
	10 tons of manure	800 lb. 4–8–10	1600 lb. 4–8–10	800 lb. 4–8–10 140 KC1 380 Super	1600 lb. 4–8–10 280 KC1 760 Super	800 lb. 4–8–10 140 KC1	800 lb. 4–8–10 380 Super
	Potato yields: bushels per acre						
Blocks	1	2	3	4	5	6	7
C	218.36	272.10	265.33	362.82	278.82	346.02	356.10
B	215.00	288.90	167.84	315.78	278.82	322.50	238.52
A	292.26	450.15	228.22	436.72	396.38	403.10	256.10
Total	725.62	1011.15	762.99	1111.32	954.02	1071.62	950.72
Average	241.87	337.05	254.19	**371.77***	318.00	357.20	316.90

* Plot 4 of the three blocks (C.B.A.) was treated according to Pilote Soil Test.

Table 6 gives the potato yields of 1941. This experiment is the same as that of the preceding year, 1940, with the exception of the amount of the fertilizer applied since the field used did not show the same soil test results.

TABLE 6.—POTATO YIELDS IN 1941

	Treatments					
	10 tons of manure	800 lb. 4–8–10	1600 lb. 4–8–10	1750 lb. 4–8–10	3500 lb. 4–8–10	800 lb. 4–8–10 190 lbs. KCl
	Potato yields: bushels per acre					
Blocks	1	2	3	4	5	6
C	136.3	132.0	165.3	181.3	123.3	149.4
A	111.7	139.2	147.5	134.9	104.4	149.0
B	68.2	92.8	88.5	74.0	60.9	59.9
Total	316.2	364.0	400.0	390.0	288.0	368.9
Average	105.0	121.0	**133.0**	130.0*	96.0	123.0

* Plot 4 of the three blocks (C.A.B.) received the application determined by the Pilote Soil Test.

The highest yield obtained for three consecutive years on potato plots where fertilizer treatments were based on the Pilote Soil Tests demonstrates the adequacy and reliability of the Pilote Test as an indication of the soil deficiency and requirements.

Barley Experiment

The barley yields shown in Table 7 were taken on 1940 potato plots in order to study the residual effect of fertilizers applied in 1939.

TABLE 7.—RESIDUAL EFFECT OF FERTILIZERS ON BARLEY

Blocks	Barley yields—bushels per acre						
	1	2	3	4	5	6	7
A	46.17	44.84	45.79	50.64	50.92	34.87	51.49
B	29.73	43.32	54.63	45.51	40.28	37.34	45.51
C	45.51	31.44	50.45	50.54	48.26	35.34	43.42
Total	121.41	119.60	150.87	146.69	139.46	107.55	140.32
Average	40.5	39.8	50.3	**48.9***	46.5	35.8	46.8

* The three plots No. 4 received the treatments prescribed by the Pilote Soil Tests.

Turnip Experiment

The experiment shown in Table 8 was carried on turnips in 1941 on a farm at L'Islet. The experiment comprised 9 different treatments repeated three times, making a total of 27 plots. Three of those treatments were based on Pilote Soil Tests. The other plots served as checks for comparison.

TABLE 8.—TURNIP YIELDS IN 1941

	Treatments (700 lbs. per acre)								
	1	2	3	4	5	6	7	8	9
	2-0-0	2-9-6	2-18-12	2-0-6	2-0-12	2-18-0	2-18-6	2-0-12	2-9-9
	Yield of turnips: tons per acre								
Blocks	1	2	3	4	5	6	7	8	9
A	19.4	23.2	26.5	22.5	28.3	24.5	16.2	21.8	20.7
B	16.2	25.2	23.6	14.7	25.8	20.0	18.5	21.0	21.0
C	18.2	30.0	19.2	13.7	22.3	17.2	16.3	15.8	20.1
Total	53.8	78.4	69.3	50.9	76.4	61.7	51.0	58.6	61.8
Average	17.9	**26.1***	23.1	16.9	25.5	20.6	17.0	19.5	20.6

* The three plots No. 2 received the treatment prescribed by the Pilote Soil Test.

These five experiments on potatoes, barley, and oats, respectively are presented to illustrate correlation of crop response with results as evidence of the Indicateur Pilote Rapid Chèmical Soil Test.

FERTILITY LEVEL INDICATED BY THE INDICATEUR PILOTE

In order to bring about further proof of the adequacy of the Pilote Soil Test a few series of soil samples were collected on different fertilizer plots of known crop response.

Table 9 gives the potash analytical data on 6 series of soil samples collected at different dates for 3 consecutive years. The first 2 series of soil samples were taken in 1939 on potato plots, the second 2 series were taken on oat plots in 1940, and the last 2 series were collected on clover plots in 1941. The experimental field is located at the Experiment Station of Ste-Anne de la Pocatière.

TABLE 9.—RESULTS OF POTASH TESTS MADE ON SOIL SAMPLES COLLECTED ON FERTILIZER PLOTS AT DIFFERENT DATES FOR THREE YEARS

No.	1939		1940		1941	
	June 27	July 25	July 18	Sept. 16	July 22	Sept. 16
63	325	200	200	75	300	225
72	300	200	150	100	275	200
71	400	225	175	110	400	275
60	425	200	200	100	325	225
53	400	250	200	100	325	200
56	325	200	200	100	225	150
55	300	225	200	90	375	200
54	500	300	250	100	200	200
70	450	250	225	200	300	250
67	325	300	275	100	400	275
66	300	275	250	100	300	200
65	400	250	200	90	300	175
62	300	275	200	90	325	275
61	300	200	225	100	300	150
51	400	235	235	125	375	200
50	450	300	200	110	300	200
59	550	200	225	100	400	300
68	400	300	300	200	300	200
58	725	300	225	80	275	175
64	700	425	225	100	265	225
57	1100	300	375	90	275	100
52	625	325	375	280	475	300

Figure 5 presents a compilation of the preceding potash test results. The soil samples were distributed into 4 groups according to the amount of potash that each received. The first group received no potash treatment; the second group received an average of 61 lb. of KCl per acre; the third group received an average of 154 lb. of KCl per acre; and the fourth group received an average of 248 lb. of KCl per acre.

An average of the test results was taken from each group and is illustrated in Figure 5. At the ordinate, the potash test results are expressed in pounds per acre, and at the abscissa are the different dates upon which the samples were collected.

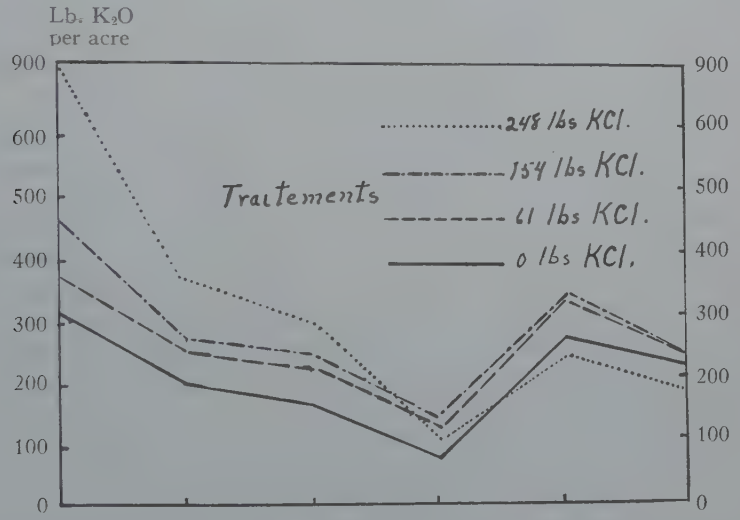

FIGURE 5. Potash Test Results obtained from six series collected at Different Dates on Fertilizer Plots.

The test results correspond well with the different potash treatments. The test results decrease in proportion as the potash treatments decrease and this from June 27, to September 16, 1940. At that last date the soil seems to have lost all of its potash treatment since the tests on all the plots are equivalent. During the summer 1941 the two series of soil samples showed higher test results compared to those of September 16, 1940. The explanation of such a raise in available soil nutrient in 1941 is difficult. It might be attributed to the dry summer of that season 1941, which may have developed a higher concentration of the soil solution.

Table 10 presents phosphorus tests results made on the same series of soil samples for which the potash results have been described.

TABLE 10.—PHOSPHORUS TEST RESULTS OBTAINED FROM SOIL SAMPLES TAKEN ON DIFFERENT FERTILIZER PLOTS AT DIFFERENT DATES SINCE 3 YEARS

No.	1939		1940		1941	
	June 27	July 25	July 18	Sept. 16	July 22	Sept. 16
63	5	2	10	5	0	0
67	2	5	0	0	10	15
66	10	25	5	0	10	15
60	10	5	10	0	0	10
56	5	15	0	0	0	10
55	5	5	0	0	10	0
54	10	5	0	0	10	10
53	10	10	0	0	15	10
70	10	10	0	0	15	10
71	10	10	10	0	25	15
72	2	5	10	0	10	15
65	15	5	10	0	10	10
59	50	40	10	0	15	15
61	60	50	0	0	10	10
62	10	60	10	0	10	10
51	10	40	20	0	0	10
50	50	60	20	0	25	15
58	125	75	10	5	10	15
64	150	100	25	0	0	10
68	50	150	50	10	20	20
57	150	75	10	0	10	20
52	40	20	50	20	0	20

As in Figure 5, the following Figure 6 presents a compilation of the phosphorus test results. The test results have been divided into 4 groups according to the amount of superphosphate that the plots have received. The first group of plots received no treatment; the second group received 170 lb. of superphosphate per acre; the third group received 310 lb. of superphosphate; and the fourth group received 613 lb. of superphosphate.

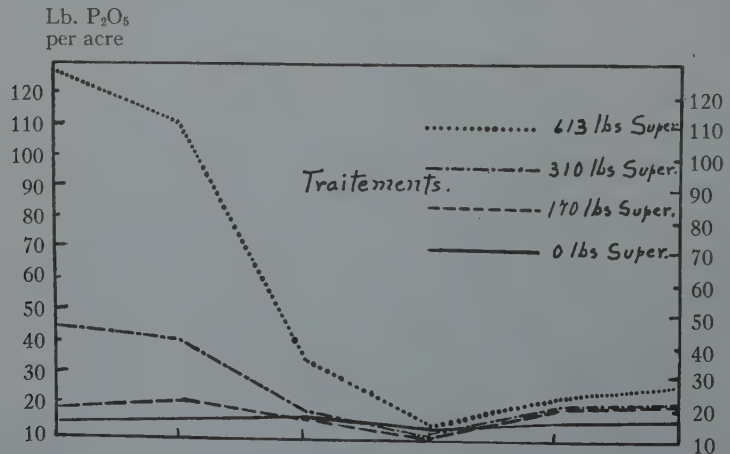

FIGURE 6. Phosphorus Test Results Obtained from Six Soil Series taken at Different Dates on Different Fertilizer Plots.

The superphosphate treatment on the different groups of plots had its marked effect on the rapid soil test from June 27, 1939, until September, 1940. At that date, the soil shows only traces of readily soluble phosphorus.

SUMMARY

In order to avoid the handicaps of the analysis for the total amount of mineral constituents of soils and to provide a reliable index of fertility needs, an attempt was made to develop and standardize a rapid soil test for Quebec soils.

Different methods were examined at the laboratory of the Agricultural College of Ste-Anne de la Pocatière. The results were not satisfactory. Most of them showed poor correlation with the soil treatments and crop response.

Through modifications of the Thornton and Morgan methods for phosphate and potash, respectively, the authors succeeded in calibrating a new method. This was done with the help of field experiments combined with the standard biological method of Neubauer.

"L'Indicateur Pilote" which was so adapted was put to the test on different soil types. The experiment was carried on potatoes for a period of 3 years and on barley and turnips for 1 year.

Plot yields were the highest when the fertilizer recommendations were based on "Indicateur Pilote." The value of these tests seems, therefore, quite reliable.

"L'Indicateur Pilote," like any other method, is valuable only to the extent that it is carefully made and well interpreted, and should not be taken as a "cure-all," for the problem of estimating soil fertility levels is a multi-dimensional one requiring patient and constant research on the part of soil scientists.

It is believed, however, that the new soil test kit proposed is an improvement on existing methods for some Quebec soils and it is the hope that it will be of great benefit to the farmers of the province.

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REPORT ON EFFECT OF CERTAIN CULTURAL AND FERTILITY PRACTICES ON THE PROTEIN CONTENT OF WHEAT[1]

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INTRODUCTION

This study of the effect of various cultural and fertilizer treatments on the protein content of wheat was conducted as a supplementary project by the Soils Department of the University of Manitoba, and was financed by a special grant under the Prairie Farm Rehabilitation Act.

The wheat samples used in this study were obtained from the sub-projects on the Fertility Field of the University Farm, Winnipeg. These fertility experiments were instituted in 1919, and include: Fallow Frequency, Crop Sequence, Green Manure, Barnyard Manure, and Commercial Fertilizer sub-projects. The field experiments were not planned primarily to provide grain for protein studies, but the various plots already established provided the best collection of comparable material available for such study.

Following some initial work in 1929, protein analyses were made of the wheat grown on certain of these plots, to ascertain the effect of the respective treatments on the protein content of wheat on blackearth soils. In 1932, the initial studies were extended to other sub-projects, and they have been continued to date.

The soil on which these experiments were conducted is of the clay textured blackearth type, on which a slight invasion of poplar had occurred prior to breaking in 1912. In 1932, forty-four surface samples (0 to 6″ deep) were gathered from the experimental plots. On analysis it was found that the carbon content of these soil samples averaged 4.54% and the nitrogen content averaged 0.370% so that the organic matter may be calculated as being approximately 8%. Thus, although the soil of the experimental field has a lower organic content than the best medium to medium heavy textured blackearth soils, nevertheless, it may be considered as quite representative of the heavy textured bleackearth soils of the Red River Valley.

EXPERIMENTAL DATA AND RESULTS

A brief outline of each of the respective experiments and the results obtained are presented under sub-project headings as follows.

1. Fallow Frequency

In this sub-project, wheat was grown exclusively with different frequencies of fallow, i.e.: *(a)* fallow every second year; *(b)* fallow every third year; and *(c)* fallow every fourth year.

[1] Conducted at the Soils Laboratory, University of Manitoba, in co-operation with the Dominion Experimental Farms Service, by special grant under the Prairie Farm Rehabilitation Act.
[2] Soils Department, University of Manitoba, analytical work by H. A. Scott, J. M. Parker, R. E. Wicklund, W. A. Ehrlich, of the Dominion Experimental Farms, under Prairie Farm Rehabilitation Act., Ottawa.

In each of the various fallow frequencies wheat crops were grown with the following treatments:

(1) No fertilizer or manure.

(2) Ammonium phosphate (11–48) drilled-in with the seed at 45 pounds per acre.

(3) Barnyard manure, at 4 tons per acre, applied in the fall prior to the crop year.

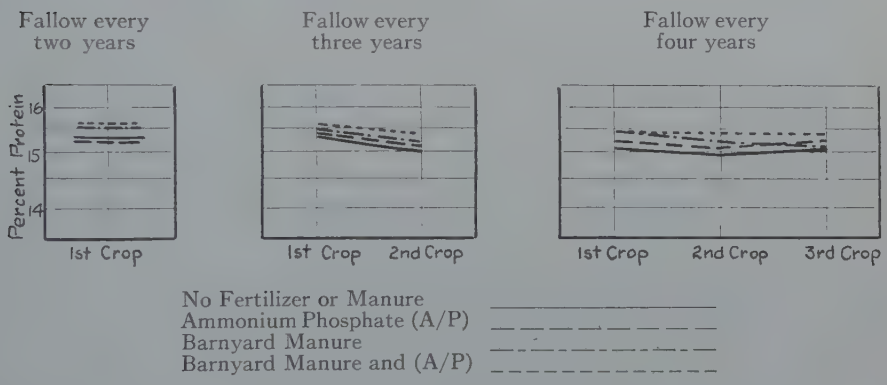
(4) Barnyard manure as in (3) combined with ammonium phosphate as in (2).

The effect of the respective fallow frequencies and fertilizer treatments on the protein content, the weight per bushel, the yield of grain, and the yield of straw per acre, are presented as 10-year averages (1932-1941) in Table 1.

The average protein content of the wheat grown under the various fallow frequencies and fertilizer treatments for the ten-year period, and the general mean protein content of the wheat from all the different treatments by years is shown graphically in Figure 1.

FIGURE 1.—EFFECT OF FREQUENCY OF FALLOW ON PROTEIN CONTENT OF WHEAT

Mean Protein Content of Wheat after Fallow Frequencies



Average Protein Content by Years, 1932 to 1941

(Mean of all Treatments)

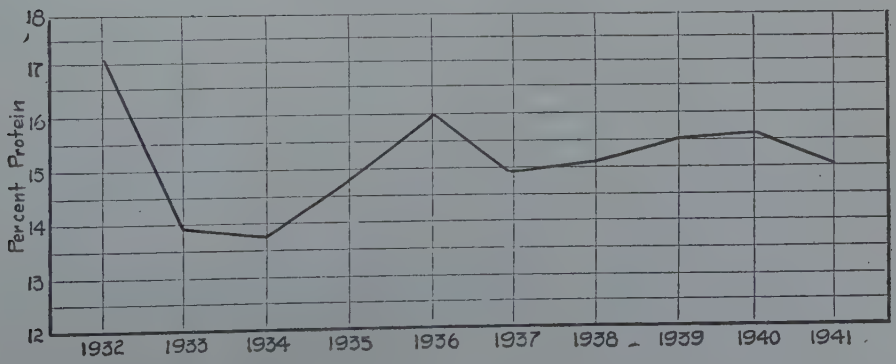


TABLE 1.—MEANS OF PROTEIN CONTENT, WEIGHT PER BUSHEL, YIELD OF GRAIN AND YIELD OF STRAW PER ACRE OF WHEAT GROWN IN FALLOW FREQUENCY EXPERIMENT FOR THE 10-YEAR PERIOD, 1932–1941

Yield data and fallow frequency	Fertilizer and manure treatments				Mean of all treatments
	None	Ammonium phosphate	Barnyard manure	Manure and ammonium phosphate	
Protein content in %	%	%	%	%	%
Fallow every 2nd year:					
1st crop wheat	15.28	15.25	15.51	15.64	15.42
Fallow every 3rd year:					
1st crop wheat	15.38	15.43	15.49	15.60	15.47
2nd crop wheat	15.01	15.19	15.27	15.45	15.23
Fallow every 4th year:					
1st crop whea	15.02	15.36	15.43	15.47	15.32
2nd crop whe	14.98	15.23	15.34	15.48	15.36
3rd crop whea	15.02	15.37	15.36	15.48	15.31
Mean of all plots	15.11	15.30	15.40	15.52	15.33
Weight per bushel in lb.	lb.	lb.	lb.	lb.	lb.
Fallow every 2nd year:					
1st crop wheat	61.62	61.87	61.50	61.42	61.60
Fallow every 3rd year:					
1st crop wheat	61.47	61.96	61.39	61.26	61.52
2nd crop wheat	61.47	61.99	61.72	61.82	61.75
Fallow every 4th year:					
1st crop wheat	61.86	62.07	61.85	61.58	61.84
2nd crop wheat	61.24	61.76	61.72	61.50	61.55
3rd crop wheat	60.87	61.37	61.53	61.48	61.31
Mean of all plots	61.42	61.84	61.62	61.51	61.60
Grain per acre in bu.	bu.	bu.	bu.	bu.	bu.
Fallow every 2nd year:					
1st crop wheat	35.20	38.70	33.25	34.84	35.50
Fallow every 3rd year:					
1st crop wheat	30.40	34.60	35.63	36.63	34.33
2nd crop wheat	28.00	28.48	30.52	31.03	29.51
Fallow every 3rd year:					
1st crop wheat	28.03	33.57	34.02	35.25	32.71
2nd crop wheat	24.21	27.17	27.55	28.61	26.88
3rd crop wheat	22.86	24.08	25.23	25.30	24.32
Mean of all plots	28.12	31.10	31.03	31.94	30.55
Straw per acre in lb.	lb.	lb.	lb.	lb.	lb.
Fallow every 2nd year:					
1st crop wheat	3,736	3,943	3,141	3,563	3,596
Fallow every 3rd year:					
2nd crop wheat	3,084	3,513	3,530	3,803	3,482
	2,542	2,491	2,770	2,698	2,625

TABLE 1—MEANS OF PROTEIN CONTENT, WEIGHT PER BUSHEL, YIELD OF GRAIN AND YIELD OF STRAW PER ACRE OF WHEAT GROWN IN FALLOW FREQUENCY EXPERIMENT FOR THE 10-YEAR PERIOD 1932–1941—*Concluded*

Yield data and fallow frequency	Fertilizer and manure treatments				Mean of all treatments
	None	Ammonium phosphate	Barnyard manure	Manure and ammonium phosphate	
	lb.	lb.	lb.	lb.	lb.
Fallow every 4th year:					
1st crop wheat	2,603	3,482	3,223	3,669	3,244
2nd crop wheat	2,275	2,506	2,579	2,676	2,509
3rd crop wheat	1,974	2,225	2,218	2,458	2,219
Mean of all plots	2,702	3,027	2,910	3,145	2,946

These results indicate that the variations in the protein content of the wheat due to frequency of fallow, or to treatment with ammonium phosphate or manure, were of little practical significance. However, the variations due to seasons were strongly marked. The annual general mean protein content ranged from 17.2% in 1932 to 13.8% in 1934 (see Figure 1).

Table 1 shows that the yields of wheat and straw increased as the frequency of fallow increased, but the mean differences in weight per bushel were of little or no significance.

Although the increased yields of grain with ammonium phosphate or with manure were practically the same, if expressed as the mean of all fallow frequencies, it is important to observe that ammonium phosphate gave the best response where fallow was most frequent, whereas the barnyard manure gave the best response where the fallow was less frequent. It is also significant to note that where increase in yield of wheat was obtained by the use of ammonium phosphate and barnyard manure, the protein content of the wheat was not reduced. (See sub-project 6 re the effect of phosphate.)

2. FALLOW *vs.* CLOVER OR GRASSES AND PARTIAL FALLOW

In this sub-project 3 crops of wheat, grown in succession after black summer fallow, were compared with 3 crops of wheat in succession after clover and partial fallow, and with 3 crops of wheat in succession after mixed grasses and partial fallow.

The crop rotations for the 3 series were as follows:

—	Fallow series (a)	Clover series (b)	Grass series (c)
Rotation year 1	Fallow only	Clover and partial fallow	Grasses and partial fallow.
Rotation year 2	Wheat	Wheat	Wheat.
Rotation year 3	Wheat	Wheat	Wheat.
Rotation year 4	Wheat	Wheat and sow sweet clover.	Wheat and sow timothy, meadow fescue and slender wheat grass mixture.

One range carrying each series of plots received no barnyard manure and one range carrying each series of plots was manured. One-half of each plot of wheat, manured and not manured, received ammonium phosphate (11–48), at 45 pounds per acre, drilled-in with the grain; the other half was not treated. With each series therefore, there were 4 treatments:

(1) No manure or fertilizer; (in series *(b)* and *(c)* clover or grass was plowed-in in Year 1, and fallowed for the remaining part of the season. This is referred to as partial-fallow).

(2) Barnyard manure; (in series *(a)* 4 tons of barnyard manure per acre were applied in the fall prior to each grain crop).

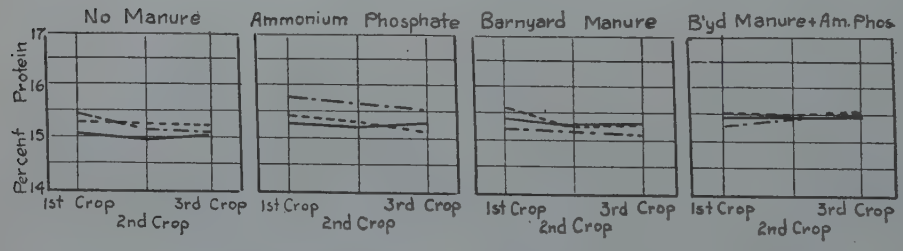
In series *(b)* and *(c)* the clover or grass was cut for hay and 10 tons of barnyard manure applied before plowing in Year 1.

FIGURE 2.—EFFECT OF USING FALLOW, SWEET CLOVER, AND GRASSES ON THE PROTEIN CONTENT OF WHEAT.

Rotation,—			
Year 1.	Fallow	Year 1. Sweet Clover and Fallow	Year 1. Grass and Fallow
Year 2.	Wheat	Year 2. Wheat	Year 2. Wheat
Year 3.	Wheat	Year 3. Wheat	Year 3. Wheat
Year 4.	Wheat	Year 4. Wheat	Year 4. Wheat

Average per cent. protein: 1932 to 1941

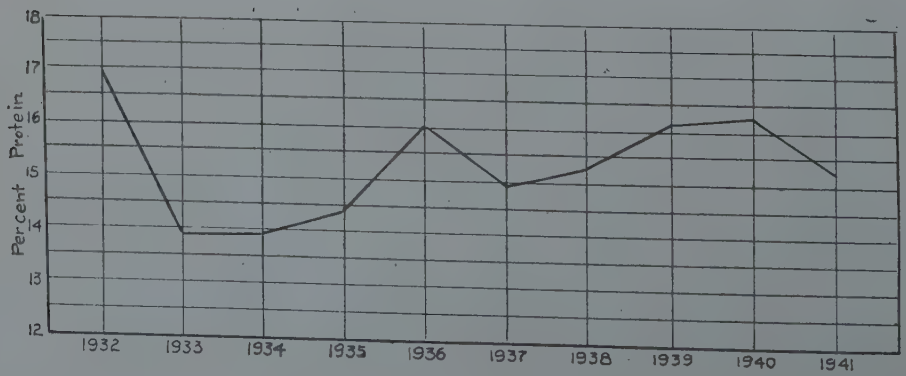
(10-year average)



Fallow Series
Clover Series
Grass Series

Average Protein Content by Years, 1932 to 1941

(Mean of all Treatments)



(3) Ammonium phosphate (11–48) drilled-in with the grain.
(4) Barnyard manure and ammonium phosphate.

These 3 rotations with 4 treatments thus provided 12 comparisons. The 10-year mean values for protein content, weight per bushel, yield of grain and yield of straw per acre for the wheat crops grown in this sub-project are given in Table 2.

The mean protein content of the first, second and third crops of wheat after fallow, after clover-fallow, and grass-fallow, with each of the manure or fertilizer treatments for the 10-year period, 1932 to 1941, is shown graphically in Figure 2. The general mean protein content of all the wheat crops in this sub-project by years is also shown in the same figure. The differences indicate that the sowing of clover and grasses for a short time only, had no significant effect on the protein content, or on the weight per bushel. On the other hand, the average percentage protein of the grain produced on all plots in this experiment by years, ranged from 16.97% in 1932 to 13.98% in 1933.

The use of ammonium phosphate increased the yield of grain on all treated plots by an average of 2.66 bushels per acre, and the use of manure increased the yield of grain on all treated plots by an average of 3.32 bushels per acre. The ammonium phosphate and manure combined gave an average increase of 4.36 bushels per acre. The average protein content of the grain from the plots treated with ammonium phosphate and manure was not reduced, but showed, if anything, a slight tendency towards an increase in protein and weight per bushel. The differences however, in this respect, were very slight.

Neither the use of clover and partial fallow, nor grass and partial fallow gave any increase in yield in the first succeeding crop of wheat, but it is observed that whereas the succeeding crops of wheat decreased in yield in the fallow series, and to a less extent in the clover series, the third crop of wheat in the grass series gave better average yields[4]. In the final analysis, the mean yield of all plots in each series averaged the same, and the mean protein content of the grain was within a fraction of 1%. It should be noted however, that the grass and clover in this sub-project were seeded down once every 4 years for 1 season only, and these negative results should be compared with the positive results obtained with wheat grown after grass and alfalfa seeded down for 3 years (see sub-project 4).

3. Annual Crop Sequence

In this sub-project wheat was grown in sequence after different annual grain crops. The annual crops which immediately preceded the wheat were sown both on fallow and on corn land, each of which was manured and not manured. The rotation used was as follows:

Rotation Year 1. Fallow and plow down barnyard manure at 8 tons per acre on even numbered plots. Uneven numbered plots not manured.

Rotation Year 2. Grain Crops:
Wheat (not manured and manured)
Oats (not manured and manured)
Barley (not manured and manured)
Spring rye (not manured and manured)
Flax (not manured and manured.).

[4] The difference in weight of the straw per acre was affected to some extent by the presence of weeds.

TABLE 2.—MEANS OF PROTEIN CONTENT, WEIGHT PER BUSHEL, YIELD OF GRAIN AND YIELD OF STRAW PER ACRE, OF WHEAT GROWN IN FALLOW VS. CLOVER AND GRASS WITH PARTIAL FALLOW EXPERIMENT FOR THE 10-YEAR PERIOD, 1932–1941

Rotation year	Protein content				Weight per bushel				Yield of grain per acre				Yield of straw per acre			
	Fallow series	Clover series	Grass series	Means	Fallow series	Clover series	Grass series	Means	Fallow series	Clover series	Grass series	Means	Fallow series	Clover series	Grass series	Means
	%	%	%	%	lb.	lb.	lb.	lb.	bu.	bu.	bu.	bu.	lb.	lb.	lb.	lb.
No manure or fertilizer																
1st crop wheat	15.02	15.43	15.30	15.25	61.86	61.00	61.25	61.37	28.03	27.63	27.83	27.83	2,603	2,590	2,686	2,626
2nd crop wheat	14.98	15.18	15.27	15.14	61.24	60.96	60.69	60.96	24.21	24.55	25.01	24.59	2,275	2,242	2,603	2,373
3rd crop wheat	15.02	15.11	15.25	15.13	60.87	60.78	60.57	60.74	22.86	22.51	24.11	23.16	1,974	2,393	2,534	2,300
Means	15.01	15.24	15.27	15.17	61.32	60.91	60.84	61.02	25.03	24.90	25.65	25.19	2,284	2,408	2,608	2,433
With ammonium phosphate																
1st crop wheat	15.36	15.75	15.45	15.52	62.07	61.23	61.56	61.62	33.57	30.69	30.30	31.69	3,482	2,934	3,016	3,144
2nd crop wheat	15.23	15.65	15.40	15.43	61.76	61.25	61.10	61.37	27.17	26.40	27.60	27.06	2,506	2,479	2,612	2,532
3rd crop wheat	15.37	15.53	15.11	15.34	61.37	61.46	61.32	61.38	24.08	24.13	26.21	24.81	2,225	2,314	2,449	2,329
Means	15.32	15.64	15.32	15.43	61.73	61.31	61.33	61.46	28.27	27.07	28.20	27.85	2,738	2,576	2,692	2,668
With barnyard manure																
1st crop wheat	15.43	15.20	15.57	15.40	61.85	61.13	61.38	61.45	34.02	31.50	30.48	32.00	3,223	2,918	2,949	3,030
2nd crop wheat	15.34	15.17	15.30	15.27	61.72	61.35	61.24	61.44	27.55	28.11	26.39	27.35	2,579	2,709	2,877	2,722
3rd crop wheat	15.36	15.07	15.41	15.28	61.53	61.25	61.25	61.28	25.23	26.45	26.83	26.17	2,218	2,685	2,883	2,595
Means	15.37	15.15	15.44	15.32	61.70	61.18	61.29	61.39	28.93	28.69	27.90	28.51	2,673	2,771	2,903	2,782
With manure and phosphate																
1st crop wheat	15.47	15.38	15.50	15.45	61.58	61.26	61.33	61.39	35.25	33.95	30.80	33.33	3,669	3,199	3,184	3.351
2nd crop wheat	15.48	15.46	15.49	15.48	61.50	61.30	61.27	61.36	28.60	28.80	27.94	28.45	2,676	2,875	2,836	2,796
3rd crop wheat	15.48	15.51	15.51	15.50	61.48	61.38	61.68	61.48	25.30	27.33	27.99	26.87	2,158	2,563	2,806	2,609
Means	15.48	15.46	15.50	15.48	61.52	61.28	61.43	61.41	29.72	30.02	28.91	29.55	2,934	2,879	2,942	2,918

Mean of all plots—	Mean of all plots—	Mean of all plots—	Mean of all plots—
In Fallow series = 15.29	In Fallow series = 61.57	In Fallow series = 27.99	In Fallow series = 2,657
In Clover series = 15.37	In Clover series = 61.17	In Clover series = 27.67	In Clover series = 2,658
In Grass series = 15.38	In Grass series = 61.22	In Grass series = 27.66	In Grass series = 2,786

Rotation Year 3. Wheat after different grain crops.
Rotation Year 4. Corn, and plow in 8 tons of barnyard manure per acre on even numbered plots in the fall.
Rotation Year 5. Grain crops as in Year 2 and on same numbered plots.
Rotation Year 6. Wheat after different crops as in Year 3.

In this experiment a comparison can be made of: (1) wheat with and without manure after fallow (Rotation Year 2), and with and without manure after corn (Rotation Year 5); and of (2) the residual effect on the wheat grown after different grain crops with and without manure (Rotation Year 3 and 6).

(1) The effect of fallow and corn on the following crop of wheat in this experiment is shown in Table 3. The figures in Table 3 show that the wheat grown after fallow produced more straw and that the grain had a slightly lower weight per bushel, with the tendency to a higher percentage of protein than the wheat grown after corn. Wheat after fallow also gave higher yield with barnyard manure. This increase in yield was very similar to that obtained in the fallow frequency experiment where the first crop of wheat followed fallow every fourth year.

TABLE 3.—MEANS OF PROTEIN CONTENT, WEIGHT PER BUSHEL, YIELD OF GRAIN AND YIELD OF STRAW PER ACRE OF WHEAT GROWN AFTER FALLOW AND AFTER CORN IN CROP SEQUENCE ROTATION (WITH AND WITHOUT MANURE) 10-YEAR AVERAGE (1932–1941)

Rotation	Protein content	Weight per bushel of grain	Yield of grain per acre	Yield of straw per acre
	%	lb.	bu.	lb.
Rotation Year 2				
Wheat after fallow				
Not manured	15.86	61.71	28.66	2,794
Manured	15.97	61.38	33.28	3,161
Rotation Year 4				
Wheat after corn				
Not manured	15.32	62.14	28.60	2,340
Manured	15.15	62.26	29.91	2,394

(2) The effect of growing wheat in Rotation Year 3 and 6 after 5 annual grain crops and the residual effect of the manure applied for the respective grain crops during the 11-year period (1931–1941) is shown in Table 4.

The mean figures for the yield of grain and of straw given in Table 4 show a distinctly lower trend in the wheat crop grown in sequence after annual crops following corn, compared with wheat after annual crops following fallow. Barnyard manure in this experiment, although applied at a low rate per acre (8 tons every 3 years), showed a definite residual effect by increasing the yield of wheat in every case, irrespective of the crop for which the manure was applied.

TABLE 4—MEAN PROTEIN CONTENT, WEIGHT PER BUSHEL, YIELD OF WHEAT AND YIELD OF STRAW PER ACRE, SOWN AFTER DIFFERENT GRAIN CROPS, MANURED AND NOT MANURED (11-YEAR AVERAGE, 1931 TO 1941)

Sequence and treatment	Protein content	Weight per bushel	Yield of grain per acre	Yield of straw per acre
	%	lb.	bu.	lb.
Year 3, Wheat:				
After wheat, not manured	15.22	62.08	25.99	2,422
After oats, not manured	14.97	62.55	27.59	2,287
After barley, not manured	14.56	62.15	25.74	2,260
After spring rye, not manured	15.00	62.42	25.86	2,296
After flax, not manured	15.17	62.89	25.09	2,385
Means	14.98	62.42	26.05	2,330
Year 3, Wheat:				
After wheat, manured	15.52	62.05	26.94	2,373
After oats, manured	15.00	62.56	30.33	2,596
After barley, manured	15.09	62.31	28.58	2,454
After spring rye, manured	15.18	62.46	28.47	2,558
After flax, manured	15.31	62.59	27.45	2,723
Means	15.22	62.39	28.35	2,541
Year 6, Wheat:				
After wheat, not manured	15.20	61.83	25.04	2,122
After oats, not manured	15.13	62.36	24.50	1,945
After barley, not manured	14.89	62.54	24.26	2,022
After spring rye, not manured	15.12	62.17	24.74	2,122
After flax, not manured	15.22	62.63	25.15	2,131
Means	15.11	62.31	24.74	2,068
Year 6, Wheat:				
After wheat, manured	15.49	61.48	25.16	2,060
After oats, manured	15.28	62.49	26.87	2,209
After barley, manured	15.34	61.88	26.42	2,231
After spring rye, manured	15.45	62.26	26.48	2,238
After flax, manured	15.23	62.56	27.82	2,496
Means	15.36	62.13	26.55	2,247

The differences in protein content of the wheat grown in sequence after the various grain crops however were only slight, and relatively insignificant compared to the differences due to season. The mean protein values of all wheat crops in this experiment were as follows:

After fallow	15.91%	After rye,	15.19%
After wheat	15.36	After oats,	15.09
After corn	15.23	After barley	14.97
After flax	15.23		

Thus, the mean differences where wheat followed other crops were not more than $\frac{2}{5}$ of a per cent., but the wheat after fallow showed $\frac{3}{5}$ of a per cent. advantage.

In contrast to this, the general mean protein content of all wheat crops by years in this experiment varied widely, ranging from 17.5% in 1931, to 12.8% in 1933. The average protein content of the wheat after cereals and the average protein content of all wheat crops in this experiment by years are shown graphically in Figure 3.

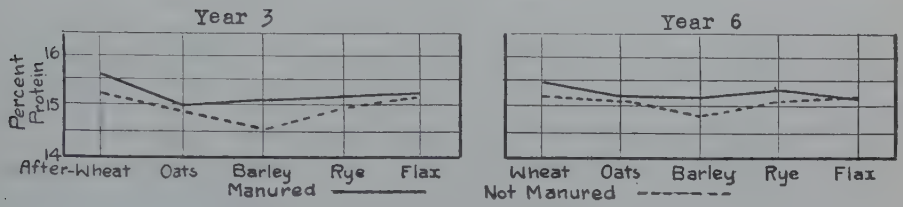
FIGURE 3.—EFFECT OF CROP SEQUENCE ON PROTEIN CONTENT OF WHEAT (1931 TO 1941)

Rotation:

Year 1.	Fallow	Year 4.	Corn.
Year 2.	Wheat, Oats, Barley, Rye, Flax, Manured and not Manured.	Year 5.	Wheat, Oats, Barley, Rye, Flax, Manured and not Manured.
Year 3.	Wheat after Annual Crops.	Year 6.	Wheat.

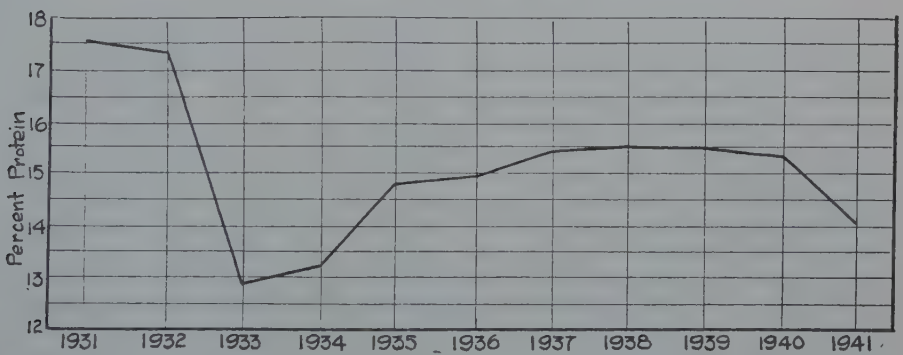
Mean Protein Content after Different Cereals

(11-Year Averages)



Average Protein Content by Years

(Mean of all Treatments)



4. EFFECT OF GRASSES AND ALFALFA

During part of the time in which samples of wheat were being collected for protein study, an experiment with methods of breaking cultivated grasses and alfalfa was conducted on the University Farm. Forty samples of wheat that was grown in the breaking experiment as first crop after grasses, grass mixtures, and alfalfa in 1932, and 60 samples of wheat that was grown as second crop after breaking grasses and alfalfa in each of the 3 years, 1930, 1931, and 1933 were available; these samples were obtained for protein analyses. Because of the fact that the breaking experiment was discontinued, comparable wheat samples available for protein study from this experiment were limited to the years mentioned. The rotations used in this experiment consisted of:—

1st year—fallow; 2nd year—seed down; 3rd year—hay; 4th year—hay and break; 5th year—one-half of each plot wheat; one-half of each plot corn; 6th year—wheat after wheat (or flax), and after corn.

The breaking methods used in this experiment with each kind of sod included:—

(1) Break 2 inches deep in summer and back-set 5 inches deep in fall.

(2) Break in summer 5 inches deep.

(3) Break in summer and double plow, 2 inches plus 3 inches, equals 5 inches.

(4) Break 5 inches deep in fall.

(5) Break in fall 2 inches deep, and back-set 5 inches deep in spring.

(6) Break in spring of Rotation Year 5 and sow flax instead of wheat on one-half of each plot; remaining half of each plot planted to corn.

(a) Wheat as first crop after breaking:

The effect of the different grasses, mixtures of grass and alfalfa, and of alfalfa, on the protein content of the first crop of wheat grown in Rotation Year 5 after 5 methods of breaking each kind of sod is indicated by the figures shown in Table 5.

TABLE 5—PROTEIN CONTENT OF WHEAT AFTER GRASSES AND LEGUMES—1932 (MEAN OF 5 WHEAT CROPS AFTER 5 METHODS OF BREAKING)

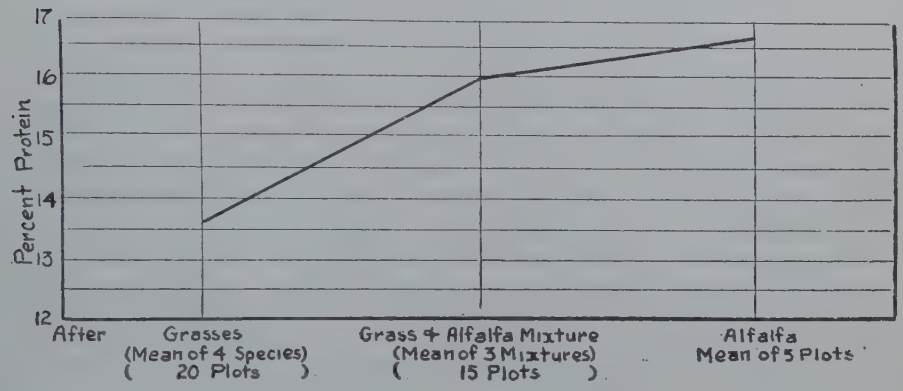
Sequence	Protein content	Means
	%	
Wheat after:		
Meadow fescue	13.18	
Brome	13.34	
Slender wheat grass	14.24	Mean of wheat after 20 plots of grasses = 13.58%.
Timothy	13.56	
Wheat after:		
Alfalfa and slender wheat grass mixture	15.46	
Alfalfa and meadow fescue mixture	16.56	
Alfalfa, meadow fescue and timothy mixture	15.60	Mean of wheat after 15 plots of grass and alfalfa mixtures = 15.87%.
Wheat after alfalfa	16.56	Mean of wheat after 5 plots of alfalfa = 16.56%.

Although only 1 year's samples of grain after breaking were available, the results for the 40 samples of wheat grown in 1932 are so emphatic and so significant that they are included in this presentation. The important point to note is that alfalfa did not raise the protein content of the wheat crops, grown on the black-earth soil where this experiment was conducted, above the average of the wheat grown on the Fertility Field, but the grasses did markedly depress the protein content of the wheat crop grown as first crop after breaking. Moreover, the alfalfa in the alfalfa-grass mixture

more or less offset the depressing effect of grass on the protein content of the following crops[5] (see Figure 4).

FIGURE 4.—EFFECT OF GRASSES AND ALFALFA ON THE PROTEIN CONTENT OF WHEAT

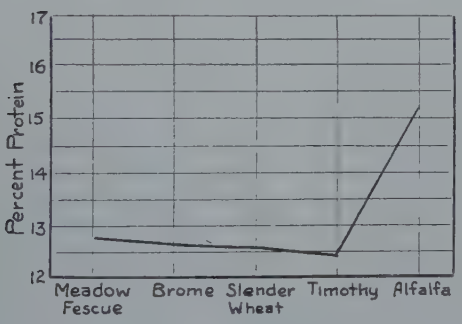
First Crop after Breaking (1932 only)



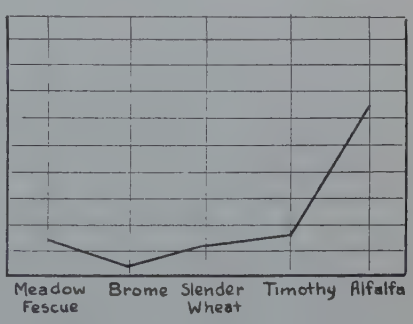
Second Crop after Breaking (1930, 1931 and 1933)

(3-Year Average)

Wheat following wheat after breaking



Wheat following corn after breaking



(b) Wheat as second crop after breaking:

Samples from 60 plots of wheat following wheat and flax after breaking, and wheat after corn after breaking, in Rotation Year 6, were available for protein analyses during each of the 3 years, 1930, 1931, and 1933. The mean protein content and the yield of grain per acre are given in Table 6 (see also Figure 4).

The figures in Table 6 bring out very forcibly the depressing effect of grass on the protein content and yield of wheat grown as second crop after breaking. There were no grass-alfalfa mixtures included when the plots on which these crops were grown were seeded down. Hence in the wheat crops grown as second crop after breaking, comparisons can only be made of the effect of grass alone compared with alfalfa alone.

[5]Due to a certain amount of shattering of the grain in the stook by sparrows, yield data in this case were not comparable. It is observed however that the yield of wheat after alfalfa and alfalfa-grass mixtures was markedly higher than after grasses. (See results in second crop after breaking.)

TABLE 6.—MEAN PROTEIN CONTENT AND YIELD OF WHEAT PER ACRE GROWN AS SECOND CROP AFTER SIX METHODS OF BREAKING GRASSES AND ALFALFA* (1930, 1931 AND 1933)

Sequence	Protein content Means of 1930, 1931, 1933		Yield of grain per acre Means of 1930 and 1933† only	
	%	%	bu.	bu.
Wheat after wheat (or after Flax‡) after—				
Meadow fescue	12.73	Mean after all grass plots = 12.59	17.46	Mean after all grass plots = 16.64
Brome	12.57		13.35	
Slender wheat grass	12.58		17.05	
Timothy	12.49		18.69	
Wheat after alfalfa	15.44	15.44	28.96	28.96
Wheat after corn after—				
Meadow fescue	12.56	Mean after all grass plots = 12.54	19.08	Mean after all grass plots = 20.51
Brome	12.28		19.30	
Slender wheat grass	12.57		21.13	
Timothy	12.77		22.52	
Wheat after alfalfa	15.21	15.21	32.80	32.80

* Grass and legume mixtures were not included at the time these blocks were seeded down.
† See foot note re damage by birds, 1932.
‡ See rotation and treatment outline under section 4, Effect of Grasses and Alfalfa.

The residual depressing effect of grass on the protein content of wheat was in evidence in each of the 3 years for which data are available (Table 7).

TABLE 7.—COMPARISON OF PROTEIN CONTENT OF WHEAT CROPS SOWN AS SECOND CROP AFTER GRASSES AND ALFALFA BY YEARS (1930–1931 and 1933)

Year	Mean protein content of wheat			
	Second crop after grasses		Second crop after alfalfa	
	%	Mean of	%	Mean of
1930	12.11	(48 plots)	14.13	(12 plots)
1931	12.82	(48 plots)	17.38	(12 plots)
1933	12.77	(48 plots)	14.45	(12 plots)
Means	12.56		15.32	

It is pointed out in the introduction that the plots from which the wheat samples were obtained were not planned primarily for protein studies. It is unfortunate therefore that no attempt was made during the years in which samples were collected to obtain data on the amount of nitrate-nitrogen in the soil during the growth of the crops. However, in 1929, before these studies were undertaken, soil samples were collected in May and July of that year from the plots in the breaking experiment (Rotation Year 5), and the amount of nitrate-nitrogen in the surface soil (0 to $6\frac{2}{3}$ inches deep) was determined.

As the figures thus obtained for nitrate-nitrogen in the soil throw light on the differential availability of nitrate-nitrogen after grass and legumes, they are here submitted in Table 8.

TABLE 8.—TOTAL NITROGEN, AND NITRATE-NITROGEN IN THE SOIL TO A DEPTH OF $6\frac{2}{3}$ INCHES, IN MAY AND JULY, 1929, FIRST YEAR AFTER BREAKING, BREAKING EXPERIMENT, ROTATION YEAR 5, TOGETHER WITH YIELD OF WHEAT GROWN IN SAME YEAR

—	Total soil nitrogen	Nitrate-nitrogen in surface soil		Yield of grain per acre	Number of plots
		May	July		
	%	p.p.m.	p.p.m.	bu.	
After grasses	.341	26	22	13.5	20
After alfalfa	.384	251	28	29.7	5

It is suggested that the explanation for the depressing effect of pure stands of grass on the yield and protein content of the wheat may be due to the well-known wide carbon : nitrogen ratio of the grass roots and residues. This experiment points forcibly to the conclusion that on the blackearth soils, the use of pure stands of grass alone in rotations cannot be expected to increase either the yield or quality of subsequent wheat crops. The reverse is to be expected. The beneficial effects of grasses on the physical conditions of the soil, and the necessity of using grasses more extensively for the prevention and control of soil drifting on arable soils is admitted and advocated, but the writer would strongly urge the necessity of using legumes in appropriate mixtures with grasses, in order to maintain yield and quality in subsequent grain crops, as well as to improve the quality and yield of forage and fodder. When grown for soil improvement, grasses and legumes must be combined if both the physical and chemical condition of the soil is to be improved.

5. GREEN MANURE

In this sub-project wheat was grown after either fallow, or after green manure crops plowed down once every 4 years, in a 4 year rotation, as follows:

Rotation Year 1, Fallow or green manure,
Rotation Year 2, Wheat,
Rotation Year 3, Corn,
Rotation Year 4, Wheat and seed down clover where required.

The treatments on the respective plots in Year 1 were:—

(a) Fallow only,

(b) Non-Legumes plowed in during the fallow year:

Weeds — Spring rye
Buckwheat — Corn.

(c) Legumes plowed in during the fallow year:

Peas
Sweet clover (sown in Year 4)
Red clover (sown in Year 4).

(d) Fallow and apply 10 tons rotted barnyard manure per acre.

The effect of these 9 treatments on the protein content, weight per bushel, yield of grain, and yield of straw per acre of the wheat crop following the green manure crops and fallow in Year 2, and the residual effect of the treatments on the wheat crop, following corn in Year 4, for the 11-year period (1931–1941) is shown in Table 9.

TABLE 9.—MEAN PROTEIN CONTENT, WEIGHT PER BUSHEL, YIELD OF GRAIN AND YIELD OF STRAW PER ACRE OF WHEAT GROWN IN GREEN MANURE EXPERIMENT FOR 11-YEAR PERIOD (1931–1941)

Treatment	Protein content	Weight per bushel	Yield of grain per acre	Yield of straw per acre
	%	lb.	bu.	lb.
Year 2: Wheat grown as first crop after—				
(a) Fallow	15.49	62.39	31.06	2,991
(b) Non-legumes	15.10	62.58	30.39	2,769
(c) Legumes	15.52	62.01	28.75	2,719
(d) Fallow and manure	15.40	62.18	35.64	3,415
Means	15.38	62.29	31.46	2,976
Year 4: Residual effect; wheat after corn of Year 3—				
(a) After fallow	15.10	62.53	29.42	2,515
(b) After non-legumes	14.76	62.71	29.17	2,399
(c) After legumes	15.23	61.75	30.35	2,551
(d) After fallow and manure	15.22	62.12	30.37	2,765
Means	15.08	62.28	29.84	2,733

In this sub-project the most significant results noted are the increased yields of straw and of grain in the wheat crop following fallow (Year 2), and in the increased amount of straw produced by the residual effect of the manure in Year 4. The differences in protein content of the wheat due to green manures are of little significance, although there appears to be a slight tendency for the protein content of the wheat after non-legumes to be depressed slightly. The wheat crops grown after fallow and green manures in Year 2 also tend to be slightly higher in protein than the wheat crops grown after corn in Year 4. The mean protein content of the wheat grown after the different treatments, and the general mean protein content of all crops by years is shown graphically in Figure 5.

6. COMMERCIAL FERTILIZERS

In this sub-project commercial fertilizers were applied to wheat in a 4-year rotation consisting of:

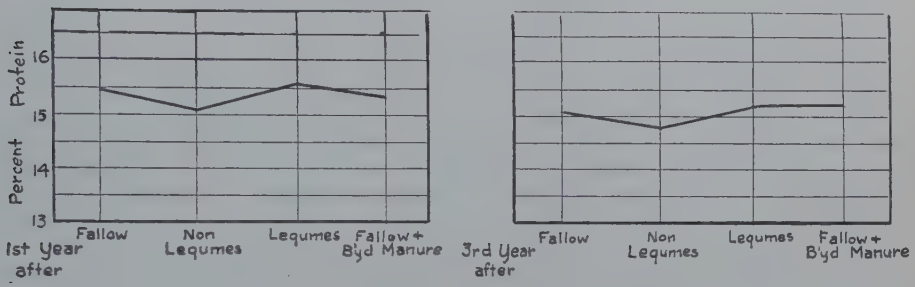
Rotation Year 1, Fallow
Rotation Year 2, Wheat
Rotation Year 3, Corn
Rotation Year 4, Barley

Fertilizers were applied broadcast prior to the seeding of wheat in the spring of Year 2. Where manure was used, 10 tons per acre were applied

FIGURE 5.—EFFECT OF GREEN MANURE ON PROTEIN CONTENT OF WHEAT, 1931 TO 1941.

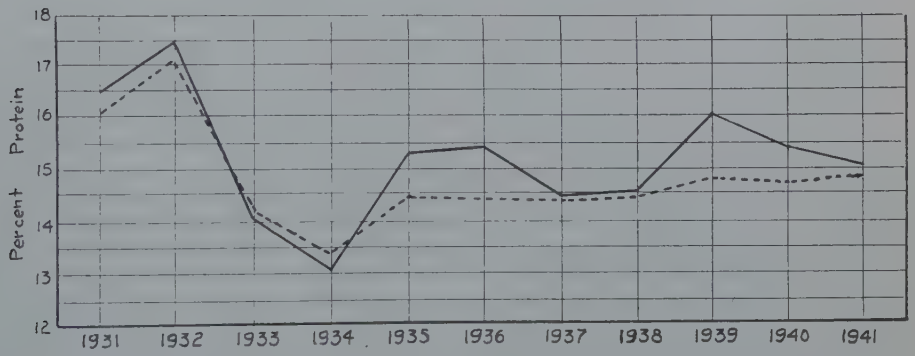
Rotation:
Year 1. Green Manure, or Fallow
Year 2. Wheat.
Year 3. Corn.
Year 4. Wheat.

Mean Protein Content due to Treatment
Average—1931 to 1941



Average Protein Content by Years
(Mean of all Treatments)

Year 2. After Fallow
Year 4. After corn



to the respective plots in Year 1. The various fertilizers applied were:—ammonium sulphate at 225 pounds per acre as a carrier of nitrogen; triple-superphosphate at 200 pounds per acre as a carrier of phosphate; and potassium sulphate at 200 pounds per acre as a carrier of potash. The plots on which these 3 fertilizers were used singly and in all possible combinations, constituted one section (6–a) of this experiment.

In addition to the fertilizer comparison, barnyard manure at 10 tons per acre, barnyard manure and phosphate, and barnyard manure and lime; in comparison with check, phosphate alone, and lime alone constituted another section, (6–b). Where lime was used it was applied at the rate of 3,000 pounds of hydrated lime per acre.

Section (6-a): Effect of Fertilizers Alone:

The mean protein content, weight per bushel, yield of grain and yield of straw per acre for all wheat crops grown with and without nitrogen,

with and without phosphate, and with and without potash during the eleven years, 1929, 1931 to 1938, and 1940 to 1941, are given in Table 10.

TABLE 10.—MEAN PROTEIN CONTENT, WEIGHT PER BUSHEL, YIELD OF GRAIN AND YIELD OF STRAW PER ACRE OF WHEAT GROWN IN COMMERCIAL FERTILIZER EXPERIMENT FOR 11-YEAR PERIOD (1929, 1931 TO 1938, 1940 TO 1941)

Fertilizer treatment, alone or in combination	Protein content	Weight per bushel	Yield of grain per acre	Yield of straw per acre
	%	lb.	bu.	lb.
With nitrogen	15.56	61.82	33.78	3,262
Without nitrogen	15.02	61.91	34.20	3,270
With phosphate	15.16	61.87	36.16	3,491
Without phosphate	15.42	62.00	31.81	3,041
With potash	15.30	62.13	33.64	3,272
Without potash	15.26	61.75	34.34	3,259

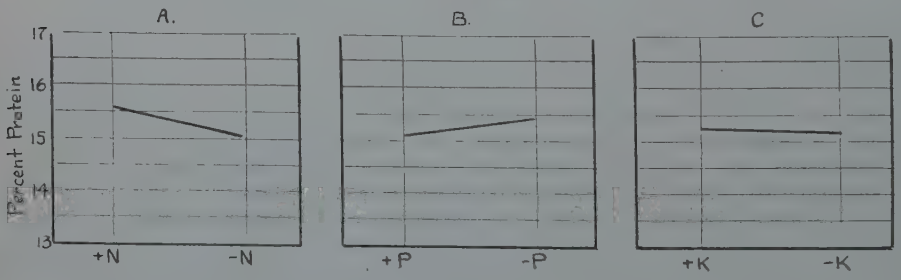
FIGURE 6.—EFFECT OF FERTILIZERS ON PROTEIN CONTENT OF WHEAT 1929, 1931 TO 1938, AND 1940 TO 1941.

Rotation:

Year 1. Fallow. Year 3. Corn.
Year 2. Wheat (Fertilized). Year 4. Barley.

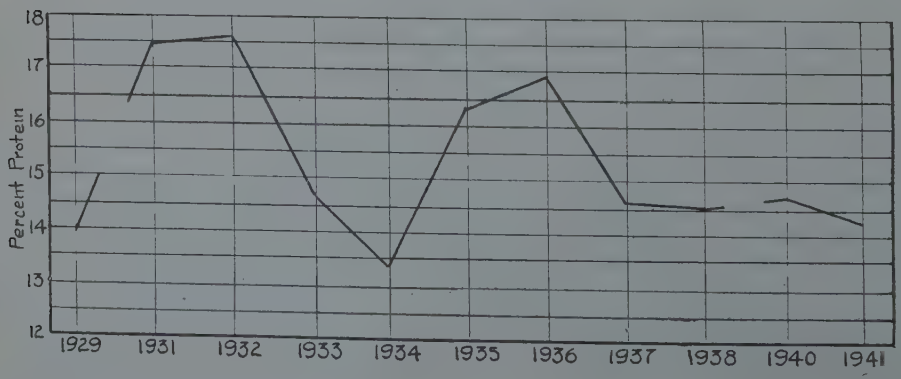
Mean Protein Content, after Fallow, of all Combinations of Treatments, with and without, (A) *Nitrogen,* (B) *Phosphate,* (C) *Potash*

(11-Year Average)



Average Protein Content by Years, 1929, 1931 to 1938, and 1940 to 1941

Mean of all Fertilizer Treatments



The mean differences in protein content of the wheat due to treatment and to years are shown graphically in Figure 6. These point to the conclusion that nitrogen alone or in combination had a tendency to increase the protein content of the wheat, that phosphate had a slight tendency to decrease the protein content, and that potash had no appreciable effect. However, the differences in protein content due to fertilizer treatment were very small compared with the wide difference due to season. The general mean protein content by years for all wheat crops in this experiment varied from 17.55% in 1932 to 13.55% in 1934.

The outstanding results shown in this sub-project (where wheat was grown after fallow) are the increased yields of wheat and of straw where phosphate was applied alone or in combination, whereas nitrogen and potash showed no beneficial effect in this respect. The results from this sub-project are of special interest when compared with those from the Fallow Frequency project. In the Fallow Frequency experiment reported as sub-project 1, ammonium phosphate (11–48) drilled-in with the seed, gave significant increases in yield of grain, but no decrease in protein content. The nitrogen, in the 11-48 ammonium-phosphate used in sub-project 1, apparently offset any slight tendency indicated in sub-project (6-a) of the phosphate to depress the protein content.

Section (6-b).: Effect of Barnyard Manure alone, Barnyard Manure reinforced with Phosphate, and Barnyard Manure with Lime; compared with no Manure, no Phosphate, and with Lime.

The effect of phosphate, and of lime when used with and without barnyard manure on the protein content of wheat, weight per bushel, yield of grain and yield of straw per acre in this section of the fertilizer experiment for the 11-year period, 1929, 1931 to 1938, and 1940 to 1941, are shown in Table 11.

TABLE 11.—MEAN PROTEIN CONTENT, WEIGHT PER BUSHEL, YIELD OF GRAIN AND YIELD OF STRAW PER ACRE, OF WHEAT GROWN WITH MANURE REINFORCED WITH PHOSPHATE AND WITH LIME IN COMMERCIAL FERTILIZER EXPERIMENT FOR 11-YEAR PERIOD (1929, 1931 TO 1938, AND 1940 TO 1941)

Treatment	Protein content	Weight per bushel	Yield of grain per acre	Yield of straw per acre
	%	lb.	bu.	lb.
Manure and phosphate	14.82	62.55	37.56	3,640
Phosphate only	14.76	62.25	37.15	3,509
Manure and lime	15.36	62.57	37.72	3,620
Lime only	14.97	62.12	30.21	2,780
Manure	15.01	62.23	37.10	3,580
None (check)	15.21	62.70	30.95	3,091

The only marked differences shown in Table 11 are the increased yield of grain and of straw where either manure or phosphate was used. Lime used with barnyard manure showed little or no effect on the protein content of the wheat, but it showed a tendency to depress the amount of growth

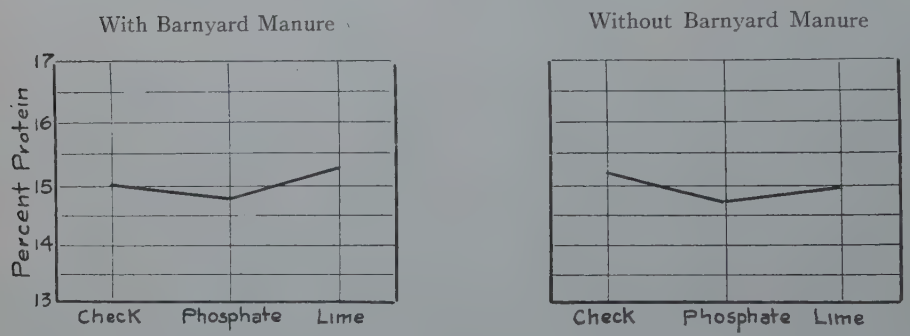
when used alone. This depressing effect of lime on growth was offset when manure was used with the lime. This indicates the value of barnyard manure on high-lime soils.

The slight variation in protein content of the wheat due to treatment in this section of the experiment, and the wide variations in the general means in the different years are shown graphically in Figure 7. The slight tendency for phosphate to lower the protein content is indicated.

FIGURE 7.—EFFECT OF PHOSPHATE AND LIME WITH AND WITHOUT MANURE

Mean Protein Content of Wheat after Fallow

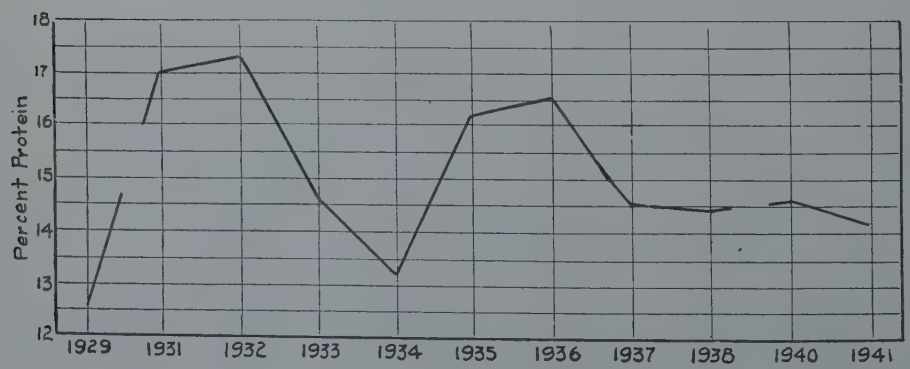
(11-Year Average)



Average Protein Content of Wheat by Years

1929, 1931 to 1938 and 1940 to 1941

(Mean of all above Treatments)



SEASONAL VARIATION

The foregoing results, in general, have shown that the variations in protein content of wheat that occurred on blackearth soil due to such different treatments as Fallow Frequency, Annual Crop sequence, Green Manure, Fertilizer and Barnyard Manure, etc., were either of comparatively minor order, or of little practical significance. The mean values, where minor differences appeared, differed generally by a fraction of 1% only. The exception to this generalization is the marked depression in protein content of the wheat that occurred when it was sown as first and

second crop after breaking cultivated-grass-sod. On the other hand, the yearly mean protein content of all the wheat samples for the different years showed a wide range of values. These seasonal variations were of a major order and ranged from an annual mean of 17.2% to 13.24%.

In this connection, the following qualifying notation must be made by way of explanation. In any one year, the same variety of wheat was grown in all sub-projects, but during the 12-year period (1929–1941), 3 different varieties of wheat were used. The change in wheat varieties was made so that the standard wheat variety recommended for the district by the cerealists would be used in the cultural and fertility experiments. Hence the annual variations in protein content which occurred are made up of variation due to seasonal influences, and variation due to the variety of wheat used. To what extent the seasonal mean values for protein were influenced by the variety of wheat used cannot be checked by the records of this experimental field, because one variety only was used in any one season. However, as the highest and lowest records of protein values (in 1932 and 1929 respectively), were obtained with the same variety of wheat, (i.e., Reward). and as each variety in turn showed marked variation in the successive seasons, it is obvious that the major factor in determining the protein content of wheat was seasonal and not varietal. Furthermore, the records of the various wheat crops, grown year by year in the respective sub-projects, present no evidence to indicate that any one of the three varieties reacted to the cultural or fertilizer treatments in any way differently from the others.

In Table 12, the mean protein content of the wheat by years, listed in descending order of value, and the mean weight per bushel, are given for comparison with the summary of the weather data during the 12 years in question. The precipitation for August to October prior to each crop year and the precipitation from emergence to cutting are listed together with the mean daily temperature from emergence to cutting expressed in degrees

TABLE 12—AVERAGE PROTEIN CONTENT OF WHEAT, AVERAGE WEIGHT PER BUSHEL, NUMBER OF DAYS FROM EMERGENCE TO CUTTING, AND CLIMATIC DATA ON THE UNIVERSITY FARM FOR 12 YEARS (1929–1941)

Year	Average protein content of wheat from all fertility experiments	Average weight per bushel	Days from emergence to cutting	Previous precipitation Aug. to Oct.	Mean daily temperature in degrees F. emergence to cutting	Total precipitation from emergence to cutting	Rain factor P/T −32° emergence to cutting
	%	lb.	days	inches	degrees	inches	
1932	Reward 17.22	66.5	78	8.84	33.7	5.87	.174
1931	Reward 17.04	66.8	85	4.32	32.3	5.73	.177
1939	Renown 15.76	61.1	86	2.11	30.7	5.91	.192
1936	Renown 15.75	58.8	75	7.81	34.6	4.80	.136
1940	Renown 15.65	63.5	86	5.27	30.0	8.96	.298
1938	Renown 15.06	62.5	79	5.58	32.7	6.22	.190
1935	Ceres 14.88	50.2	86	8.71	33.3	10.07	.302
1937	Renown 14.86	63.6	84	3.56	33.8	6.47	.191
1941	Renown 14.76	64.6	85	7.28	31.3	6.63	.212
1933	Ceres 13.90	63.0	79	5.48	35.3	8.45	.239
1934	Ceres 13.58	62.2	91	6.99	33.3	8.15	.245
1929	Reward 13.24	65.0	83	2.18	30.3	4.16	.152

Fahrenheit minus 32°. An attempt also has been made to express the seasonal climate as a single expression, (i.e., a "rain factor"), obtained by dividing the inches of precipitation by the mean daily temperature in degrees Fahrenheit minus 32° for the growth period from emergence to cutting.

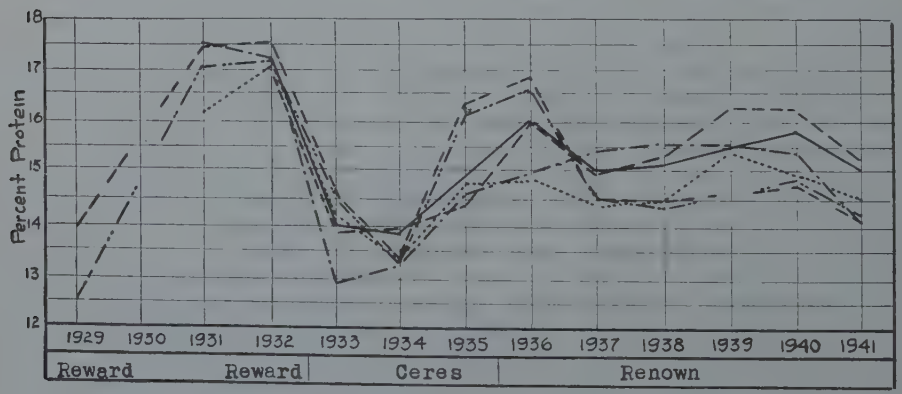
Both the rain-fall for the growing season and the seasonal "rain factor" values are erratic, and it may be pointed out that in July, 1936, a number of exceptionally hot days were responsible for the premature ripening of the grain, and for the light weight of the grain per bushel. On the other hand, the exceptionally low weight per bushel of the wheat in 1935 is a reflection of a wheat-rust epidemic.

It is evident that the weather during a specific growing season is a complex of important daily variations that cannot easily be reduced to a single "all-inclusive" expression. Hence a close correlation between protein content of the wheat and the summations of climatic data should not be expected. The data in Table 12 are presented to show the complexity of a problem, the solution of which is not here attempted.

LOCATIONAL VARIATION

An interesting fact in reference to the seasonal variation in protein content is brought out when the graphs of the average protein content by years of each sub-project are superimposed one over the other, as shown in Figure 8. This figure shows that a differential locational effect

FIGURE 8.—THE DIFFERENTIAL EFFECT OF LOCATION IN DIFFERENT YEARS, ON THE PROTEIN CONTENT, AS SHOWN BY THE MEAN VALUES FOR EACH EXPERIMENT



Experiment:
Sub-Project 1.
Sub-Project 2.
Sub-Project 3.
Sub-Project 5.
Sub-Project 6a.
Sub-Project 6b.

appears to be operative in different portions of the experimental field where the sub-projects were conducted. The graphs show that although the protein content of the wheat may be relatively high or relatively low, depending upon the season, the seasonal differences in protein content between sub-projects (or location) are not constant. For example, in 1932

and 1934, differences between the average protein content of the wheat grown in all the sub-projects in the same experimental field, were less than 1%; but in 1931, 1933, 1935, 1936, 1939 and 1940 the differences in the protein content of the wheat grown in the different sub-projects were relatively wide. As these differences were not due to management practices it would appear that some factor (or factors) is involved which causes differences to occur in the protein content of the wheat grown in different parts of the same field in one season, which is not operative to the same extent in other seasons. No explanation for this phenomenon is here attempted, but these observations point to the fact that dynamic soil conditions may be differentially affected in different parts of the same field, and that the causative factors are more influential (with one exception) than the cultural and fertility treatments used to date.

SUMMARY

This report presents the results secured to date in respect to the effect of certain cultural and fertilizer practices on the protein content of wheat grown on a heavy textured blackearth soil.

Wheat crops were grown on the University Farm, Winnipeg, over a 10- to 12-year period, under a wide range of treatments in a number of experimental sub-projects, specifically located in different parts of the same experimental field. Under the present fertility level of the heavy textured blackearth soil, seasonal influences were the dominant factors in determining the protein content of the wheat; the mean protein content of the wheat grown under different treatments in each of the respective sub-projects varied little from the general mean of the specific sub-project, but differential locational variations were apparent in different seasons; furthermore the field management practices used (with one exception) had little practical effect on modifying the protein content of the wheat.

The important exception was the marked depressing effect on the protein content, as well as on the yield of the grain and straw, when wheat was sown both as first and second crop after breaking pure stands of well-established cultivated-grass-sod. The depressing effect of the cultivated grasses on the yield and on the protein content of subsequent wheat crops was counteracted when alfalfa was used in alfalfa-grass mixtures. It is emphasized that the use of pure stands of grass alone on blackearth soils is not sound practice. Where the seeding down of blackearth soils is required for the purpose of soil improvement, it is necessary to combine both grasses and legumes in grass-legume mixtures to effect real improvement in the soil, and to maintain yield and quality in subsequent crops.

Because, no doubt, of the moderately high organic content and the favourable level of total nitrogen in the blackearth soil on which the experiments were conducted, the mean differences in the protein content of wheat treated with commercial fertilizers were slight. The application of nitrogen gave a slight but positive increase in protein content; phosphate gave a marked increase in yield of grain but showed a slight tendency to lower its protein content; and where ammonium phosphate (11–48) was drilled in with the grain, similar increases in yield were obtained, but any apparent tendency of phosphate to lower the protein content of the wheat was counteracted.

SUBSTITUTES FOR DRIED BUTTERMILK AND YELLOW CORN IN CHICK RATIONS[1]

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The relative non-availability of certain feedstuffs for use in poultry rations is caused by periodic scarcity and other economic factors. The effect of these limitations has been observed in the available volume of two widely used feeds, namely, dried buttermilk and yellow corn. In that the nutritive quality of chick starters particularly is subject to deterioration under the stress of ingredient shortages if proper attention to substitutes is not given, it would appear imperative that the specific study of replacement feeds be more intensively undertaken.

The United States Department of Agriculture (5) has recommended a variety of dried milk substitutes of which a dried brewer's yeast-fishmeal mixture would seem to be the most suitable for chick starters. In order to replace yellow corn, the obvious recourse is to utilize greater quantities of Canadian-grown cereals, namely, wheat and barley, as was suggested by the Poultry Division of the Central Experimental Farm (3).

It was the purpose of the trials reported herein to compare the relative feeding value of the staple feedstuffs with their proposed substitutes in a chick ration and to note the incidence of possible dietary irregularities resulting from the substitutions made.

EXPERIMENTAL PROCEDURE

Mixed Barred Plymouth Rock chicks from parent stock which had been nutritionally standardized were suitably randomized into 4 lots within 24 hours after hatching. For the initial 4 weeks they were reared in a uniform-temperature battery of the overhead heating type and then were transferred to a growing battery for the remainder of the 8-week experimental period. In both batteries feed and water were permitted *ad libitum*.

The 4 lots, designated as A, B, C and D, were fed rations of the composition as shown in Table 1.

Yellow corn at a level of 25% of the total ration was replaced by equal parts of wheat and barley; dried buttermilk, equivalent to 5% of the mash, was replaced with equal parts of dried brewer's yeast and fishmeal. By virtue of this substitution, the rations bearing the dried buttermilk substitute contained a slightly higher crude protein content of approximately 1%. In order to obtain a more critical comparison of the relative supplementary value of the staple feeds with their respective substitutes, a generally lower nutritional plane was obtained by elimination of soya bean

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[2] Lecturer in Poultry Husbandry, Macdonald College.

[3] Associate Professor of Poultry Husbandry and Head of the Department of Poultry Husbandry, Macdonald College.

TABLE 1.—COMPOSITION OF THE RATIONS

Ingredient	Lot A	Lot B	Lot C	Lot D
	Lb.	Lb.	Lb.	Lb.
Ground yellow corn	500	500	—	—
Ground wheat	—	—	250	250
Ground barley	400	400	650	650
Ground oat groats	200	200	200	200
Wheat middlings	250	250	250	250
Wheat bran	100	100	100	100
Fish meal (60%+)	100	150	100	150
Meat meal (55%+)	75	75	75	75
Dried buttermilk	100	—	100	—
Dried brewer's yeast	—	50	—	50
Linseed oil meal (O.P.)	75	75	75	75
Alfalfa leaf meal	100	100	100	100
Calcium carbonate	75	75	75	75
Iodized salt	20	20	20	20
Manganese sulphate	4 oz.	4 oz.	4 oz.	4 oz.
Fish oil (guaranteed 1850 I.U. Vit. A. 400 units D.)	5	5	5	5
	2000	2000	2000	2000

meal from the test rations. A plant protein of lower biological value in the form of linseed oil meal was used.

The experiment was carried out in duplicate, Trial I and Trial II, for the 8-week periods of April 22 to June 10 and June 15 to August 5 respectively. The recorded data were confined to weekly individual body weights, weekly feed consumption for each lot and incidental observations.

RESULTS

Growth Response

Data showing the average percentage rate of gain, total gain, feed consumption and feed/gain ratio are presented in Table 2.

When the growth rate is interpreted in terms of percentage rate of gain, calculated by the improved arithmetic method described by Brody (1), it is apparent that the dried brewer's yeast-fishmeal-fed lots (B and D) developed more rapidly than their controls. A comparison of similar lots between trials I and II on the basis of their total weight gains indicates that the rations containing the dried buttermilk substitute were repeatedly superior to those containing the staple dried buttermilk powder. When in combination with wheat-barley cereal, the dried brewer's yeast-fishmeal mixture gave a growth response less satisfactory than that resulting from a combination with yellow corn.

Since the growth rates recorded for chicks in lots A and C were approximately of the same order irrespective of the cereal used, an explanation appears necessary. Other essential nutrients being constant, the higher feeding value of yellow corn should be proportionate to its T.D.N., 83 lb. per 100 lb. as compared with 70 lb. per 100 lb. for the wheat-barley mixture as tabled by Titus (4). As dried buttermilk at the level of 5%

TABLE 2.—SUMMARY OF DATA ON THE AVERAGE PERCENTAGE RATE OF GAIN, TOTAL GAIN, FEED CONSUMPTION AND FEED/GAIN RATIO FOR THE EXPERIMENTAL PERIOD

Lot and Trial	Number of chicks	Average rate of gain	Total average gain	Average feed consumption per chick	Average feed/gain ratio
		%	gm.	gm.	
A					
I	64		517.0	1465	2.83
II	29		445.6	1300	2.92
Total Average	93	31.7	481.3	1382	2.87
B					
I	64		600.9	1624	2.70
II	29		555.0	1584	2.85
Total Average	93	33.6	578.0	1604	2.78
C					
I	64		539.4	1496	2.77
II	29		444.1	1256	2.83
Total Average	93	32.0	491.8	1376	2.80
D					
I	64		564.7	1605	2.84
II	26		489.4	1363	2.79
Total Average	90	32.6	527.0	1484	2.82

was an ingredient common to both rations, it would appear that the wheat-barley cereal in some way favourably supplemented the growth promoting properties of dried buttermilk.

Attention is drawn to the consistently lower total gains made in trial II. Seasonal temperatures during this trial frequently rose beyond the optimum for bird comfort and undoubtedly contributed adversely to the development of the chicks.

Feed Consumption and Feed/Gain Ratio

Feed consumption data for the various lots as recorded in Table 2 demonstrate that consistently greater quantities of feed were consumed during trial I as compared with trial II to result in correspondingly greater total gains. In both trials, however, there was a high positive correlation between feed consumption and growth response. Greatest average feed consumption per chick was recorded in lots B and D, 1604 grams and 1484 grams respectively. In these lots the rations which were fed contained dried brewer's yeast, but were unlike in cereal content. The wheat-barley mixture in the ration of lot D resulted in a lower feed consumption than was the case where yellow corn constituted 25% of the ration. Reduced consumption without the differentiation in the effect of cereal was recorded for lots A and C.

When the average feed/gain ratio was computed for each lot to serve as an index of efficiency of feed utilization no wide differences were noted. Between trials I and II lower feed/gain ratios were observed in the initial trial with the exception of lot D. Results of both trials indicated that the ration which was fed to the chicks in lot B and contained dried brewer's yeast and yellow corn produced the most efficient gains, while its control diet in lot A was the poorest in this respect. The other rations were of intermediate rank in their ability to efficiently produce gains.

Two forms of dietary abnormalities were observed. Perosis was recorded in lots A and D and therefore its occurrence could not be specifically related to any feed combination under study. At the fourth week pressure necrosis of the beak was noted in varying severity and predominated in the wheat-barley-fed lots. Poley (2) has previously associated the appearance of this beak malady with excessive fineness of the mash texture, particularly where wheat constitutes a high proportion of the cereal fraction.

SUMMARY

Substitutes for dried buttermilk and yellow corn have been studied as supplements to a nutritionally restricted basal mixture to test their replacement value in chick starters.

When compared with the control diet containing the above staple feeds, a combination of equal parts of dried brewer's yeast and fishmeal with either yellow corn or a cereal consisting of equal parts wheat and barley proved superior as indicated by faster growth and/or greater efficiency in feed utilization. With dried buttermilk the wheat-barley cereal had a value equivalent to that of yellow corn.

It is concluded that dried buttermilk and yellow corn at levels of 5% and 25% respectively may be quantitatively substituted by equal parts of dried brewer's yeast and fishmeal, and wheat-barley cereal without sacrifice of the nutritive quality of chick rations.

ACKNOWLEDGMENT

Financial assistance from the Quebec Department of Agriculture is gratefully acknowledged.

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METHODS AND RATIONS FOR FATTENING POULTRY

VII. THE COMPARATIVE EFFECT OF SINGLE GRAINS AND MIXTURES OF GRAINS, OF FINE OR COARSE GRINDING, AND OF MIXING WITH SKIM MILK OR WHEY[1]

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[Received for publication November 28, 1942]

The series of experiments dealing with fattening of poultry which has already been reported (3) has been further extended. Ground oats as a fattening feed has previously been shown to be definitely inferior to ground yellow corn for production of gain and increase in percentage fat (2). Ground oat groats, however, proved to be superior to yellow corn for production of gain and of similar value for increase in percentage fat (3). It was tentatively assumed that the removal of the hull of the oat grain to produce the groat was responsible for the improved results obtained. In order either to confirm or invalidate this assumption a sample of oats was divided into two portions, one having the hull removed mechanically before feeding so as to produce the groat, and the other being fed intact. These grains were fed singly in the ground form as the sole source of cereal in the fattening mesh. At the same time the oats and yellow corn were combined in equal proportions and fed to another group in order to determine whether any appreciable associative effect would be produced by combining these grains. As a second control on this feed mixture, the fourth group received ground yellow corn as their only cereal grain. The same sample of oats was used for all 3 groups to which this grain was fed. A similar condition existed for the 2 groups receiving ground yellow corn.

In a previous test (5), extremely fine grinding of oat groats produced a physical consistency of the wet mixed feed which had definitely lowered the palatability of the mixture to the point where only very small quantities were consumed. It was felt worth while therefore to determine whether medium-fine or coarse grinding of the cereal grain gave more satisfactory results. Throughout this presentation ground oats will refer to the oat grain including hulls whereas the term ground oat groats will designate the ground kernel only, the hull having been removed and discarded.

A practical problem relating to the most satisfactory mixer for fattening feeds was investigated namely, the substitution of whey for skim milk. During the period when a large proportion of light and heavy roasters are prepared for market, many farmers have whey at their disposal. The whey used in this instance was fresh from the vats and had not been diluted in any way. Both mixers were used at a level of equal parts by weight of mixer and ground grain.

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MATERIALS AND METHODS

Barred Rock cockerels of 28 weeks of age were used for this test. They were fattened in commercial laying batteries so that individual feed consumption figures would be available. Four groups of 36 birds each were randomized according to hatch, battery, tier in the battery, feed and treatment. The different treatments accorded the birds were as follows:—

Group A—Ground oat groats

Group B—Ground oats

Group C—Ground yellow corn

Group D—Ground oats and ground yellow corn—equal parts by weight

One-half of each of the above groups had their grain medium-finely ground, that for the remaining half being coarsely ground.

Because of difficulties inherent in an attempt to describe accurately the degree of fineness of grinding when grains of various textures are used, as was the case in these tests, it will only be stated that medium-fine grinding should be interpreted to mean fine grinding but somewhat coarser than the consistency generally called "flour" while coarse grinding would be just short of a degree which would permit the birds to pick out the coarse pieces of grain from the mixture. A further division was made in that one-half of all the birds had their ground feed mixed with skim milk and the other half of whey. The fattening period was of 2 weeks duration.

The data were analysed by the methods of variance and covariance, the criteria being gain in body weight and increase in percentage fat. The observed and adjusted means were calculated as in previously reported experiments (1, 4). The dressed carcasses were also given a commercial grading to determine differences in market quality both as to degree of fatness and colour of fat.

RESULTS

Gain in body weight and increase in percentage fat for all treatments are shown in Table 1. The necessary differences at accepted odds for both criteria are also shown for the observed means.

TABLE 1.—MEANS OF GAIN IN BODY WEIGHT AND INCREASE IN PERCENTAGE FAT

Treatment	Gain in body weight		Increase in percentage fat	
	Observed*	Adjusted	Observed*	Adjusted
	gm.	gm.	%	%
Ground oat groats	374.17	439.96	16.36	17.12
Ground oats	363.33	298.30	15.07	14.38
Ground yellow corn	350.42	374.57	15.67	15.83
Equal parts of ground oats and ground yellow corn	388.61	363.68	18.51	18.28
Medium-fine grinding	379.72	385.62	16.92	16.72
Coarse grinding	358.54	352.64	15.88	16.08
Skim milk mixed	374.58	379.88	16.52	16.63
Whey mixed	363.68	358.42	16.28	16.17

* Necessary difference for odds 19 : 1 (observed means only)—for gain—feeds (36 birds), 77.36 gms., grindings and mixers (72 birds), 54.74 gms., for increase in percentage fat—feeds 3.56%, grindings and mixers 2.52%.

It is apparent that no significant differences in actual gain in weight or increase in percentage fat have been brought about by any treatment. On the basis of these results the evidence indicates that a similar effect on gains and fat increase may be expected from the various treatments under consideration. Attention is drawn to the fact that a difference on the borderline of significance exists in increase in percentage fat between the groups receiving ground oats and the oats-yellow corn mixture.

When the adjusted means are considered, however, it is found that the group receiving ground oat groats made significantly greater gains than the one receiving oats. In other words, the removal of the hull of this sample of oats significantly increased its efficiency for the production of weight gain. When ground oats are used, therefore, similar gains may be expected to those which would be made if the hull was removed, but when the necessary adjustment is made in these data (adjusted means) so that body weight at the beginning of the experiment, initial percentage of fat, increase in percentage of fat and feed consumption are equalized, it becomes apparent that the removal of the hull gives a product, the oat groat, which is significantly more efficient in the production of gain. The difference in favour of oat groats in this instance is 32.2%. Ground oat groats is also superior to ground yellow corn in the efficiency of production of weight gain (difference 14.9%) and as might be expected to the combination of oats and yellow corn (difference 17.3%). Ground yellow corn proved to be significantly more efficient than ground oats (difference 20.4%). The combination of oats and yellow corn was also superior to the oats alone by 18%. It is worth noting in considering this comparison that the addition of yellow corn to oats gave an improvement in efficiency such that the mixture was intermediate to the 2 single ingredients. If no complimentary or associative effect had been evident the theoretically expected gain for this group would have been 336.4 grams instead of the actual 363.7 grams, a variation within the normal range of error of the experiment. Neither degree of fineness of grinding nor the mixer used had any effect upon efficiency of gain.

Considering increase in percentage fat, the combination of oats and corn was significantly more efficient than oats alone, but not significantly more so than corn. Since the ground yellow corn was not significantly more efficient than oats it must be presumed that an associative effect was evidenced in this instance and consequently that the combination of certain grains may tend to improve their efficiency over the individual grains themselves for the deposition of fat.

Table 2 following shows a summary of the grading of the dressed carcasses for degree of fatness as well as colour of fat. Such a grading translates the actual condition of fat as indicated by percentage increase in fat into practical terms which are of interest in that they show the quality of the finished carcass on the basis of their actual market value. The group fed ground oats was apparently inferior to the other three groups in production of the highest quality finish.

TABLE 2.—PERCENTAGE OF VARIOUS MARKET GRADES ACCORDING TO TREATMENT

	Milkfed A	Grade A	Total A	Milkfed B	Grade B	Total B	Total milkfed	Total grades
	%	%	%	%	%	%	%	%
Ground oat groats	80.6	—	80.6	99.4	—	99.4	100.0	0.0
Ground oats	61.1	2.8	63.9	30.6	5.6	36.2	91.7	8.3
Ground yellow corn	76.5	8.8	85.3	11.8	2.9	14.7	88.3	11.7
Gr. oats–gr. corn 50 : 50	71.4	2.9	74.3	22.8	2.9	25.7	94.2	5.8
Skim milk mixed	71.8	4.2	76.0	21.1	2.8	23.9	92.9	7.1
Whey mixed	72.8	2.9	75.7	21.4	2.9	24.3	94.2	5.8
Fine grinding	78.9	4.2	83.1	12.7	4.2	16.9	91.6	8.4
Coarse grinding	65.7	2.9	68.6	30.0	1.4	31.4	95.7	4.3

The birds having their grain coarsely ground also suffer by comparison with those receiving the same feeds medium-finely ground. As would be expected yellow corn produced a greater proportion of non-milk fed birds than the other treatments.

DISCUSSION

Previous work (3) indicating the high efficiency of corn and oat groats for production of gain in weight is confirmed by these data. It would seem possible to have approximately as great gains on oats as with oat groats or corn if a sufficient quantity of the oats is consumed as in this instance. On the basis of the same feed consumption and initial weight, however, much greater gains were actually made by both corn and oat groats thus indicating greater efficiency in the use of these feeds. Since the oat groats were made from the same sample of oats which was fed as ground oats to the comparable group it may be concluded that the reason for the consistent and definite inferiority of the oats is its large proportion of hull. Since it is well known that fibre is relatively indigestible to poultry such a result is reasonable.

The combination of equal parts of ground oats and yellow corn was, intermediate to these grains when fed singly. Though not significant, the gain exceeded expectancy on the basis of a fifty-fifty mixture of these grains. From these data there is no justification for the assumption that any associative effect of these grains upon gain in body weight or the efficiency thereof exists. This is not the case, however, with increase in percentage fat. In this instance the adjusted gain made with the mixture of oats and corn significantly exceeded not only that of the oat-fed group but also the theoretically expected gain of the combination of grains. It may be considered, therefore, that when oats and corn were combined in this instance, there was a complimentary effect of association resulting in increased deposition of fat. Whether other or all combinations of cereal grains would have an associative effect, complimentary or otherwise, is a matter for conjecture until further experiments with various combinations of grains are carried out.

While no significant differences exist between groups having the same feeds medium-finely or coarsely ground, the mean values were favourable to fine grinding for both criteria. The actual grading of the birds also favoured the finely ground feed by 14.5% difference which, taken in conjunction with the consistency of the means just referred to and the large number of birds involved, without doubt represents a real effect. It is not impossible that the difference in consistency had an effect upon assimilation which may have been expressed in the nature of a better distribution of fat in the skin. This would be apparent by careful grading and not by analyses of the skin samples.

There is no significant difference between skim milk and whey when used as a mixer. It may be presumed therefore that unwatered whey may successfully substitute for skim milk for fattening purposes.

SUMMARY

A controlled experiment involving individual fattening of 144 Barred Rock cockerels at 28 weeks of age presented experimental evidence as follows:—

1. Previous work was confirmed in that ground oat groats proved to be more efficient than ground oats for the production of gain in body weight. It was concluded that the lower efficiency of ground oats was due to the large proportion of hull characteristic of this grain. Ground oat groats was also significantly more efficient than ground yellow corn or a combination of equal parts of ground oats and yellow corn. On the basis of these and previously reported data ground oat groats is undoubtedly the most efficient of the common grains (corn, buckwheat, wheat, barley and oats) for the production of gain in body weight in fattening. Oat groats was not significantly superior to oats, yellow corn or a combination of equal parts of these grains in bringing about the deposition of fat.

(2) Ground oats were very considerably less efficient than the other grains or the combination tested in this experiment for efficiency of production of gain.

(3) A combination of equal parts of ground oats and ground yellow corn gave a significantly greater increase in percentage fat than the theoretical expectancy on the basis of the fat increase made by these grains when fed singly. In this instance the combining of these grains brought about a marked associative complimentary effect.

(4) Medium-fine as opposed to coarse grinding of the grains used in this test gave a superior dressed carcass when visually graded on the basis of fatness.

(5) Fattening rations when mixed with unwatered whey gave similar results to those obtained when skim milk was used as the mixer.

ACKNOWLEDGMENT

The co-operation of the Division of Chemistry of Science Services through carrying out of analyses of fat samples is gratefully acknowledged.

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BOOK REVIEWS

THE NATURE AND PREVENTION OF PLANT DISEASES. By K. Starr Chester, Department of Botany and Plant Pathology, Oklahoma Agricultural Experiment Station. 584 pages, illustrated, published by The Blakiston Company, Philadelphia, 1942. $4.50.

The subject is introduced by a discussion of the significance of plant diseases in agriculture, illustrated by a number of disastrous epiphytotics. This is followed in the second chapter by a description of the agencies responsible for plant diseases and an outline of the main characters used in the separation of the four main groups of the fungi.

The next five chapters deal with a description in some detail of carefully chosen diseases, grouped according to the four divisions of the causal fungi. These are followed by a chapter describing certain disease complexes, which the author refers to as "pathological syndromes". These include damping off diseases, seedling blights, root and stalk rots, and similar troubles. Treating these diseases in this way is an innovation in a plant pathological textbook and one which is to be commended.

The plant diseases caused by agencies other than fungi are described in the next five chapters. These include the ones caused by bacteria, viruses, nematodes, parasitic seed plants, and algae; also the unfavourable composition of soil and air, and adverse conditions of temperature, moisture, and light. Where these environmental factors are involved, the author groups the resulting troubles as "physiogenic diseases". These etiological discussions are followed by a consideration of the principles of plant disease control in the remaining six chapters.

The quality of paper and type in this book leaves nothing to be desired. There is a good index, great care has been used in the selection of illustrations, and the absence of typographical errors is quite remarkable. Well chosen references to literature are given at the end of each chapter, but all of those in foreign languages are excluded. The author excuses this on the ground that they would be "beyond the linguistic ability of most agricultural undergraduates".

Good judgment has been shown in the selection of diseases for detailed description. These cover a wide range of agricultural crops grown in both temperate and subtropical North America and valuable lists of resistant varieties are given in connection with each disease. Special attention also should be drawn to the final chapter, on the control of plant diseases by cultural methods. It is a compilation of all of the principles underlying the successful use of control measures with details of the preparation and use of most of the recognized protectants and eradicants.

This book is primarily designed for students taking an elementary course in plant pathology, and especially those who intend to specialize in some phase of agriculture, but it would be most useful in connection with more advanced courses in plant pathology, and indeed also to practising plant pathologists.

—F. L. D.

BOOK REVIEWS—Concluded

PARITY, PARITY, PARITY. Black, John D., Harvard Committee on Research in the Social Sciences, 1942. 367 pages. $2.00.

Interest in parity prices for agricultural products has been widespread in United States and Canada. Students of these problems should therefore welcome Dr. Black's book. It is more than just an analysis of prices. The three parities are,—parity for agriculture, parity for labour, and parity for capital. Dr. Black aptly describes parity as a balance concept. If one group gets more than its share, the rest of society gets less.

He points out that while it was agriculture that introduced the term "parity", labour has been fighting for higher wages, shorter hours, and better working conditions for many years. Capital has developed its own methods of securing its share but has suffered reverses in depression periods. Agriculture has demanded a larger share of the national income. We have the spectacle of each of these groups struggling to secure its own ends. In United States, the farm bloc, a well organized political group, vies with labour and capital and these groups often obstruct constructive action.

Dr. Black draws attention to this struggle in the first two chapters of the book and it is significant that he refers to the inability of the government in France, England and United States to take constructive action because of the influence of such powerful groups.

The author contends that lack of understanding of the problems of agriculture, labour and capital within and without these groups is liable to have serious consequences. It is his hope that this book may contribute to mutual understanding, particularly in regard to agricultural phases of the problem.

Dr. Black deals with "Agriculture Now" and "Price Control as it Now Exists" in Chapters III and IV; Chapters V to XI deal with the evolution and analysis of parity; Chapter VIII which is entitled the "Three Shares of National Income" is particularly worth while, as is Chapter IX which deals with farm incomes versus city incomes. Dr. Black contends that parity cannot be satisfactorily established in relation to a fixed base period such as 1910–1914 as was the case in the original United States legislation. He suggests that the present methods of determining parity prices are working badly. Alternative parity standards are discussed and on pages 153–4, the author sets forth the specifications of a good parity standard. These briefly are: (1) it should reflect approximately the current normal production, consumption and market price relationship between different farm products; (2) it should reflect a normal relationship between farm income and other incomes; (3) current normal income and price relationships need not be accepted at face value but may be gradually distorted to bring about needed fundamental changes—the distortion should fit in with observed trends; and (4) parity standards are better if they can be applied automatically and objectively and if they are readily understood. He discusses at length alternatives to parity such as cost of production, comparable prices and necessary prices. This, it may be suggested, is the trend of thought current in United States.

Two chapters are devoted to inflation and one to the parities during wartime. The final chapter is called "Foreword to After the War." In this, the author clearly states that it is not within the province of the book to discuss post-war problems. "Too much about the ending of the war is conjectural." On page 356, we find this interesting comment:

> "The dangers of secondary inflation must be guarded against from the outset. The more the post-war buying power can be levelled out the better. It is clear that all the measures that are used while the war is on to prevent inflation—price control, rationing, taxes, savings,—must be continued for a time afterward and only gradually relaxed. The management of the post-war will be harder than that of the war. A major reason for this is that we know less about it."

While this book was written for the general reader, university students have not been overlooked. By and large, it is a readable book; the general reader will have trouble with some of the statistical analysis, but in this reviewer's opinion the author rendered a much needed service in presenting this analysis of parity prices, parity income, and alternatives to the parity concept.

—J. Coke.

ERRATUM

In the article entitled, "Cultural Studies with Barley. IV. Summary of results for yield and malting quality", by Meredith and Olson, in the December 1942 issue of *Scientific Agriculture* (Vol. 23, No. 4), the volume and page numbers in references 1 and 2, page 246, are incorrect. The list of correct references is as follows:—

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